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Analysis of Washington State Vessel and Facility Oil Discharge Scenarios For Contingency Planning Standards

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1.0 Executive Summary

The following oil spill volumes are recommended for contingency planning standards for Washington State waters based on an analysis of US national and Washington State spills. A three-tiered analytical approach was used to develop the spill volumes.

It is important to note that the most-probable worst-case discharge volumes are based on oil spills that occurred in the US during 1985-2000. While theoretical worst-case discharges (total loss of cargo) have not occurred in US waters to date for large tankers, they have occurred in other nations. These spills are rare events but could theoretically occur in US waters and response planning must take these types of events into account as per the Oil Pollution Act of 1990.

Recommended Contingency Planning Standards For Washington State Waters

Spill Type	Oil Types[1]	Spill Volumes (gallons)		
		Median	Most-Probable WCD	Theoretical WCD
Crude Tanker CAG	C	700,000	12,000,000	32,718,000
Crude Tanker FAIL	C	3,000	3,800,000	32,718,000
Product Tanker CAG	D,G,B	700,000	12,000,000	10,941,000
Product Tanker FAIL	D,G,B	3,000	3,800,000	10,941,000
Tanker Light/Load	C,H,I	6	100,000	not defined
Tanker Pollution	C,H,I	3	50,000	not defined
Barge CAG	C,D,G,B	800	880,000	3,800,000
Barge FAIL	C,D,G,B	20	1,031,000	3,800,000
Barge Light/Load	C,D,G,B	20	155,000	not defined
Barge Pollution	C,D,G,B	2	195,000	not defined
Freighter CAG	H,I	4,200	825,600	825,600
Freighter FAIL	H,I	70	825,600	825,600
Freighter Light/Load	H,I	8	23,300	not defined
Freighter Pollution	H,I	5	93,000	not defined
Passenger Accidents	H,I,D	400	141,000	141,000
Passenger Fueling	H,I,D	15	1,000	not defined
Passenger Pollution	H,I,D	9	5,300	not defined
Fishing Accidents	D	310	165,100	165,100
Fishing Fueling	D	4	35	not defined
Fishing Pollution	D	9	120,000	not defined
Coastal Pipeline	C,G,D,B	100	1,000,000	not defined
Coastal Refinery	C,G,D,B	20	770,000	not defined
Coastal Manufacture	G,D,B	45	12,000	not defined
Coastal Storage/Fuel	C,G,D,B	20	290,000	not defined

[1]Oil types: C = crude; H = heavy fuel oil; I = intermediate fuel oil; D = diesel, No. 2 fuel; G = gasoline; B = bunker C, No. 6 fuel.
Analysis by Environmental Research Consulting

2.0 Definitions

- **Actual spill sizes:** The recorded spill volumes based on historical data records.
- **Allision:** The striking of a moving object into a stationary object. In the case of vessels, this includes a vessel striking a stationary object, e.g., a pier, or a vessel being struck by another vessel while the first vessel is stationary.
- **Collision:** The impact of two vessels each of which is in motion.
- **Historical worst-case discharge (WCD):** The spill size that represents that largest *recorded (historical)* spill size from a particular source type for a particular location (e.g, Washington State waters).
- **Illegal discharges:** Al l spills that occurred due to intentional discharges, bilge pumping, or other activities, or unintentional discharges that are not related to accidents or failures.
- **Most-probable worst-case discharge (WCD):** The largest spill size that should be expected based on historical US national data on the maximum recorded percent cargo or fuel loss. This spill volume is generally less than the theoretical worst-case discharge (WCD) unless the total loss of cargo or fuel has occurred. This has not occurred in US waters to date.
- **Percentile spills:** The n^{th} percentile spill is that spill volume which is larger than *n%* of spills for that source and type and is smaller than 100 - *n%* of spills. For example, the spill size for the "10th percentile spill" is defined as the spill size that is larger than 10% of all spills, but smaller than 90% of all spills. Likewise, the "50th percentile spill" is defined as the median spill or the spill size that was larger than 50% of all spills, but smaller than the other 50% of spills. The "95th percentile spill" is defined as the spill size that is larger than 95% of all spills and smaller than only 5% of all spills.
- **Potential spill sizes:** The potential spill volumes for historical spill data that represent the amounts that would have been spilled if theoretical worst-case discharges (WCD) had occurred.
- **Probability distribution function (PDF):** The graphed curve (function) that shows the cumulative probabilities of spill sizes from which percentile spills can be determined.
- **Structural failure:** The breaking apart of any part of a vessel/facility that is not attributable to a collision, allision, or grounding, but rather due to weakness or wearing of the structure of the vessel or facility, e.g., corrosion, or due to the impact of weather or waves.
- **Theoretical worst-case discharge (WCD):** The spill size that represents the largest *possible* oil spill from a particular source (generally, the total oil cargo or fuel on a vessel or the entire contents of a pipeline or storage tank).

3.0 Methodology

3.1 Vessel Spill Methodology

A three-fold approach was employed for determining oil spill volumes for Washington State's contingency planning standards for vessels over 300 gross registered tons (GRT). Vessel types included in the analyses included: tankers, barges, freighters (bulk carriers, container vessels, cargo vessels), fishing vessels, and passenger vessels.

1. Oil spill data from vessels over 300 GRT into US navigable waterways during the years 1985-2000 were analyzed to develop probability distribution functions (PDFs) of *actual* spill volumes and potential spill volumes (theoretical worst-case discharges). These PDFs were then analyzed to determine 10^{th}- , 25^{th}- , 50^{th}- , 75^{th}- , 90^{th}- , and 95^{th} percentile spills , and worst-case discharges (WCDs). The vessel spill data were also analyzed to determine the percentage of cargo or fuel spilled for each incident involving an accidental cause (collision, grounding, allision, sinking, structural failure, and/or fire/explosion). The cargo tanks were assumed to be 80% full and the bunker tanks were assumed to be 70% full, based on standard methodologies employed by tanker engineers and naval architects. The percentage of spills representing the different percent cargo or fuel losses were calculated.

2. The oil spills that occurred in Washington State between 1985-2000 were analyzed to determine historical and potential PDFs and percentile spills. This analysis provides an examination of the types of spills that have occurred and the spill volumes that those incidents would have involved had there been theoretical WCDs.

3. *Theoretical* future oil spill volumes were determined based on the application of the cargo- and fuel-loss percentages and probabilities for different-sized and types of vessels from US national data onto the vessel sizes and types that transit Washington State waters. This analysis provides an analysis of the potential spill volumes that should probably be prepared for in Washington state waters with current vessel traffic. The 10^{th} -, 25^{th} -, 50^{th} -, 75^{th} -, 90^{th}, and 95^{th}-percentile spills and most-probable worst-case discharge and theoretical worst-case discharge

It is important to note that this analysis does not provide an assessment of the actual risk of an oil spill occurring in Washington State waters. The analysis only provides an assessment of the types of spill volumes that might be expected when spills do occur. A theoretical worst-case discharge (total loss of oil cargo) from a fully-loaded large tanker has not occurred to date in US waters, though a few such incidents (involving the sinking or hard drift groundings of fully-loaded tankers) have occurred in foreign waters. It is still a theoretical possibility that such a spill could occur in Washington State and other parts of the US.

3.2 Facility Oil Spill Methodology

Oil spill data from coastal facilities (storage facilities, refineries, manufacturing facilities, oil terminals, coastal pipelines) into US navigable waterways during the years 1985-2000 were analyzed to develop probability distribution functions (PDFs) of *actual* spill volumes. It was not possible to determine potential spill volumes (theoretical worst-case discharges) as the amount of oil in the facilities is not easily determined and WCDs are not defined for many facilities. The PDFs were then analyzed to determine 10^{th}- , 25^{th}- , 50^{th}- , 75^{th}- , 90^{th}- , and 95^{th} percentile spills , and worst-case discharges (WCDs) based on actual spill sizes only.

It is important to note that this analysis does not provide an assessment of the actual risk of an oil spill occurring in Washington State waters. The analysis only provides an assessment of the types of spill volumes that might be expected when spills do occur. A theoretical worst-case discharge (total loss of oil from a large facility) has not occurred to date in US waters, though a few such incidents have occurred in foreign waters. It is still a theoretical possibility that such a spill could occur in Washington State and other parts of the US.

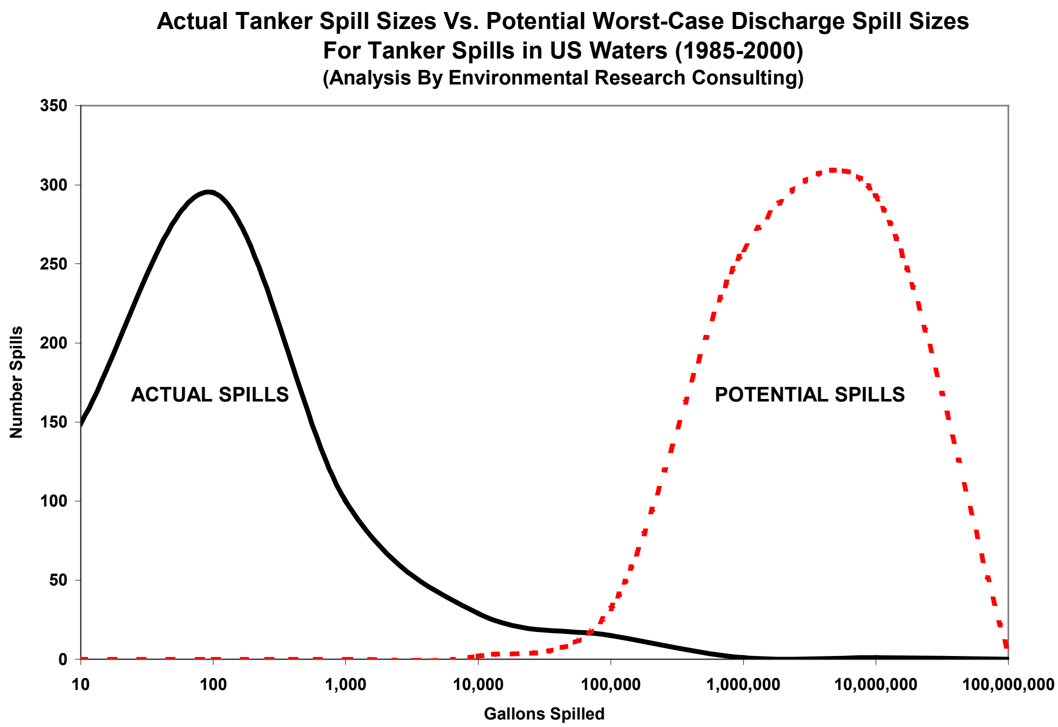
4.0 US Vessel Oil Spills Analysis

4.1 US Tanker Oil Spills

4.1.1 US Tanker Spills -- All Spill Causes

The actual and potential (theoretical) WCD spill sizes for tanker spills in US waters, *regardless of the cause* of the spills, is shown in Figure 4.1. Excluding all spill of less than 1,000 gallons (which excludes most lightering, illegal spillage incidents, etc.) the same curves are shown in Figure 4.2.

Figure 4.1



The probability distribution functions (PDFs) for actual spill sizes and potential (theoretical) WCDs for tanker spills in US waters are shown in Figures 4.3 and 4.4. The resulting percentile spills are shown in Table 4.1. This analysis shows WCDs for all types of spills regardless of cause. Since in practicality, the WCDs may not be applicable for spills related to bunkering, lightering, and loading activities, or other discharges not directly related to an accident, such as a grounding or collision. For this reason, the analyses were repeated based on spill cause.

Figure 4.2

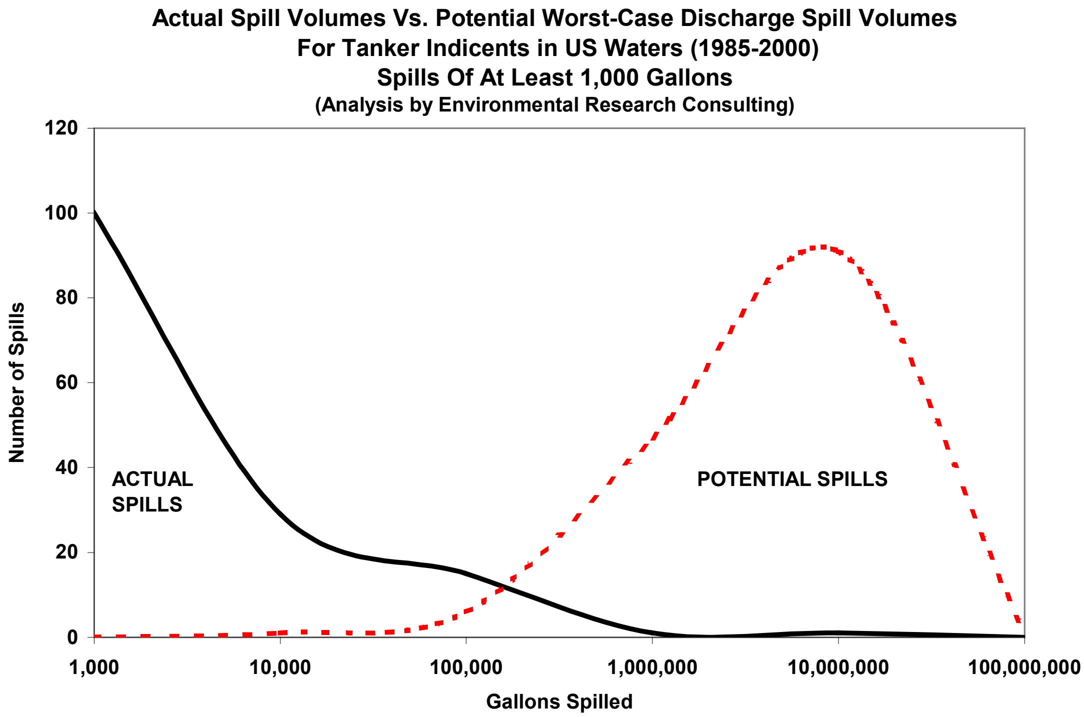


Figure 4.3

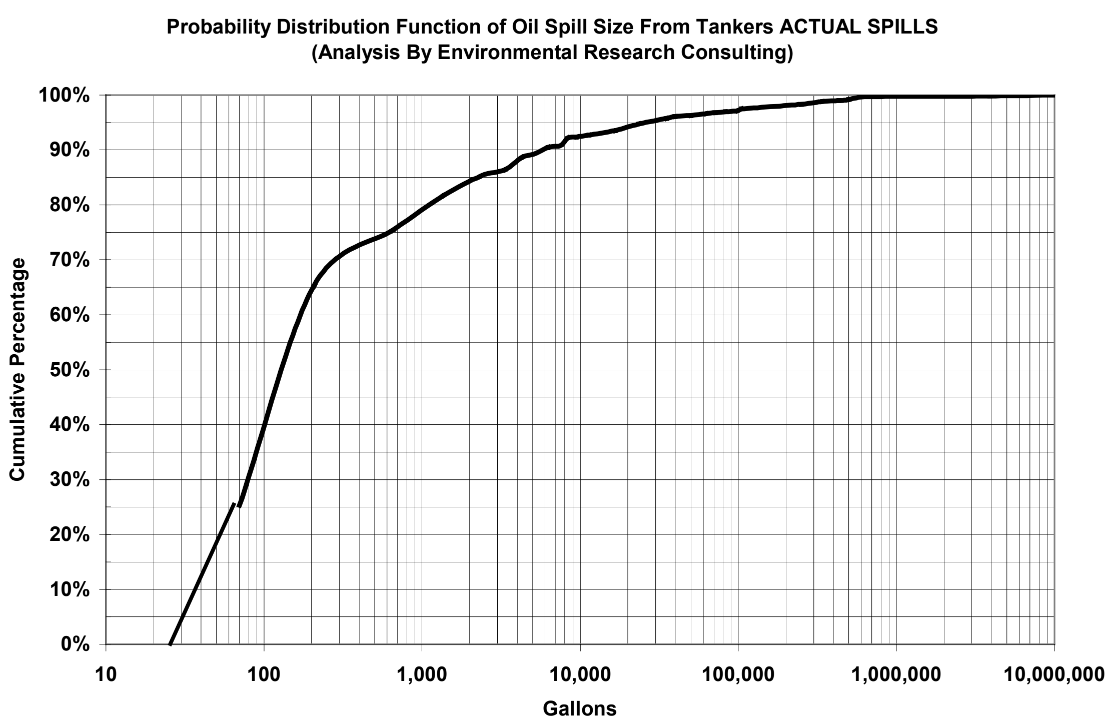


Figure 4.4

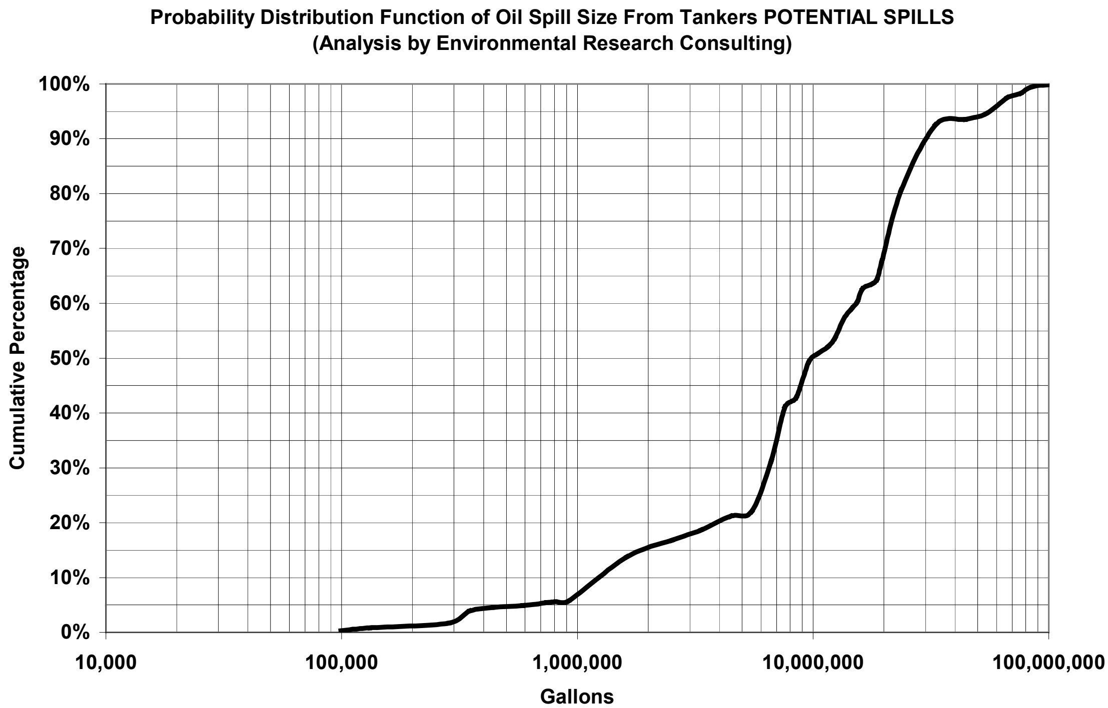


Table 4.1

Actual Vs. Potential Oil Spill Volumes From Tankers In US Waters (1985-2000) ALL CAUSES		
Percentile Spill	**Actual**	**Potential**
10th percentile	35 gal	1,100,000 gal
25th percentile	70 gal	6,000,000 gal
50th percentile	125 gal	10,000,000 gal
75th percentile	600 gal	21,000,000 gal
90th percentile	6,000 gal	30,000,000 gal
95th percentile	30,000 gal	55,000,000 gal
Worst Case Discharge[1]	11,000,000 gal	108,000,000 gal

[1]Actual WCD = historical WCD or most-probable WCD; Potential WCD = theoretical WCD.
Analysis by Environmental Research Consulting

4.1.2 US Tanker Spills – Accidents

The actual and potential oil spill volumes from tanker accidents involving collisions, allisions, and groundings are shown in Figure 4.5. The corresponding PDFs are shown in Figures 4.6 and 4.7.

The percent cargo loss (assuming 80% capacity) and the probability of each percent loss (represented by the percent total spill) are shown in Figure 4.8.

Figure 4.5

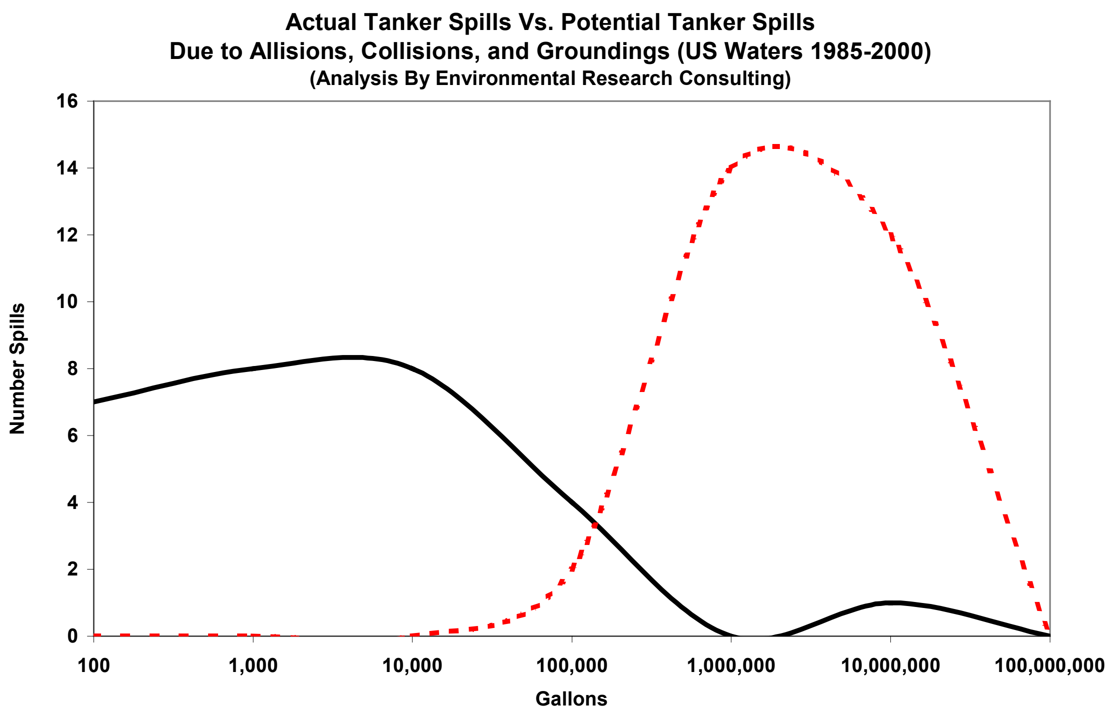


Figure 4.6

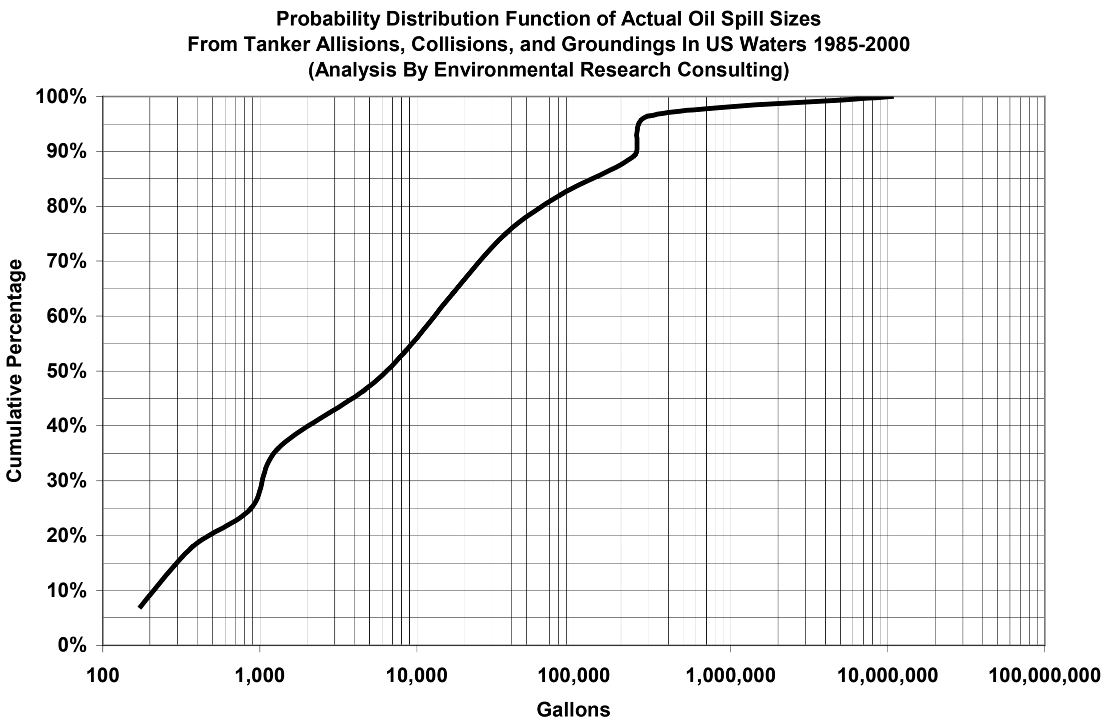


Figure 4.7

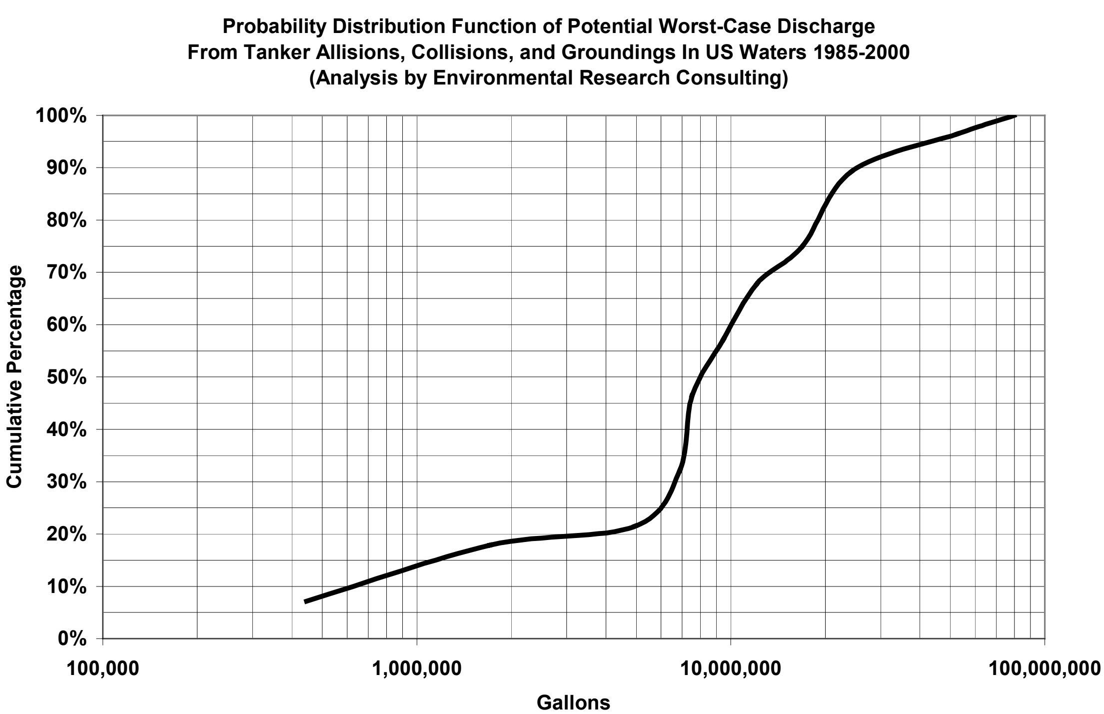
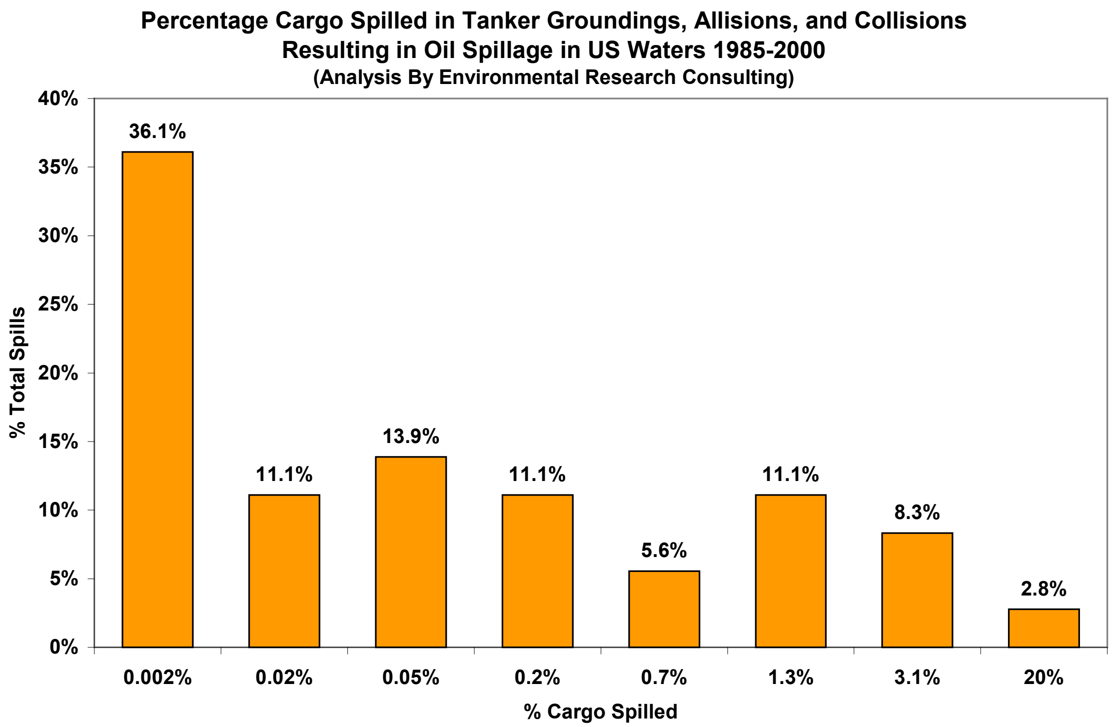


Figure 4.8



The analysis was repeated for tanker spills involving structural failure, fires or explosions, and sinking, as shown in Figures 4.9 – 4.12.

Figure 4.9

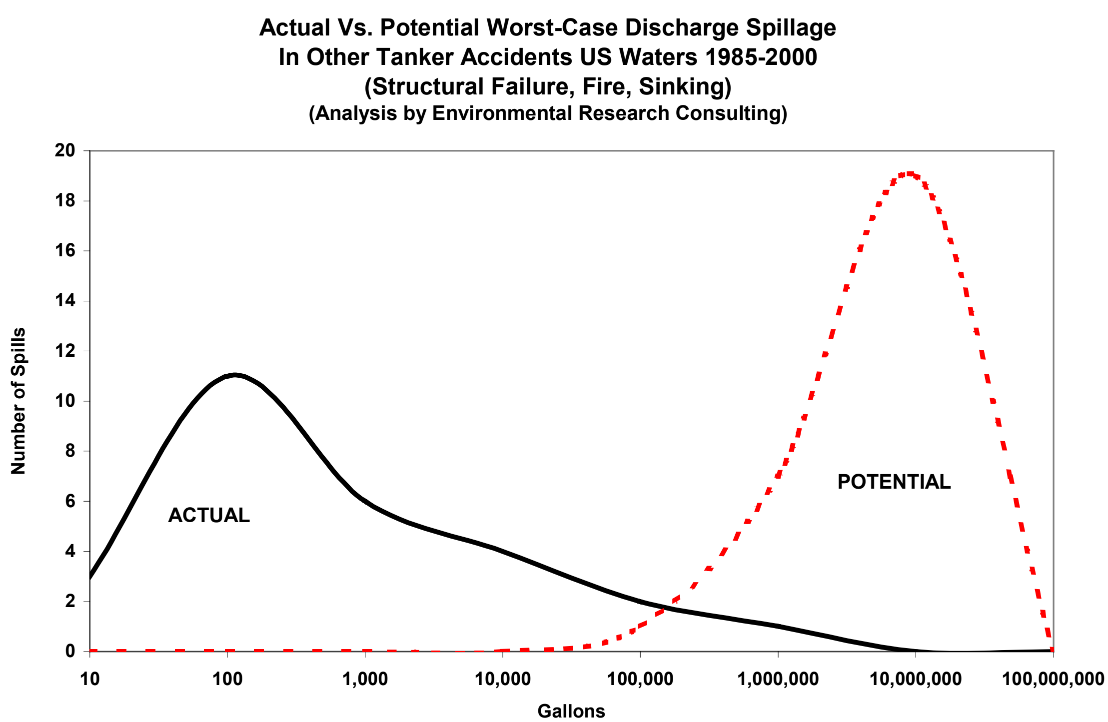


Figure 4.10

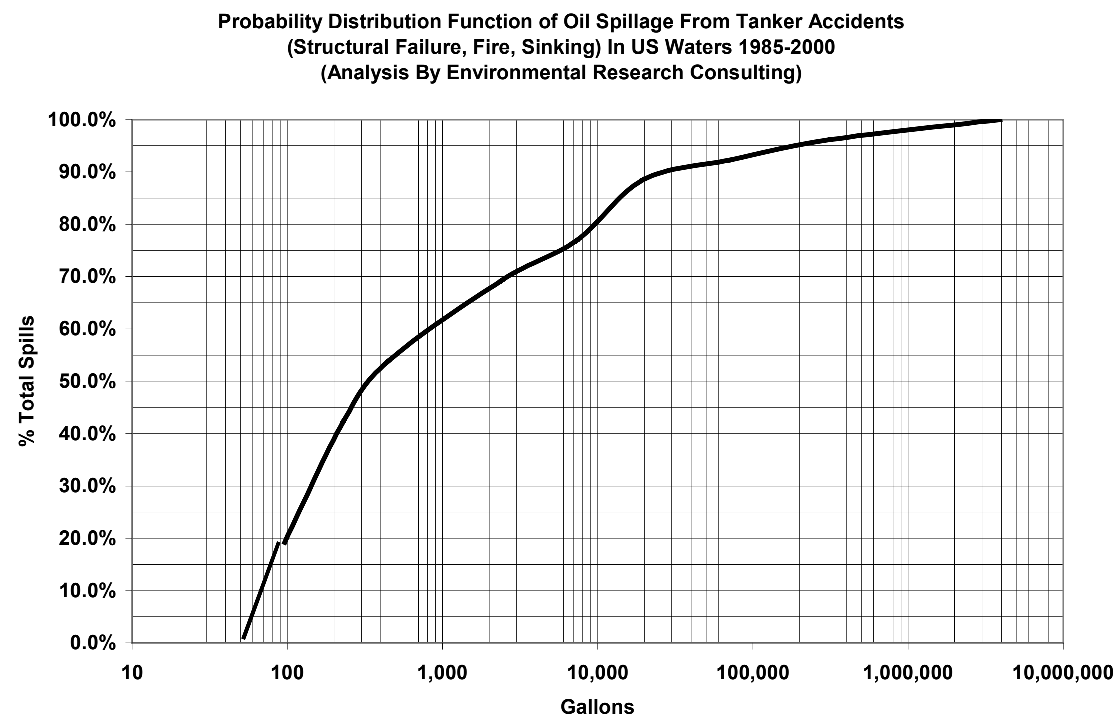


Figure 4.11

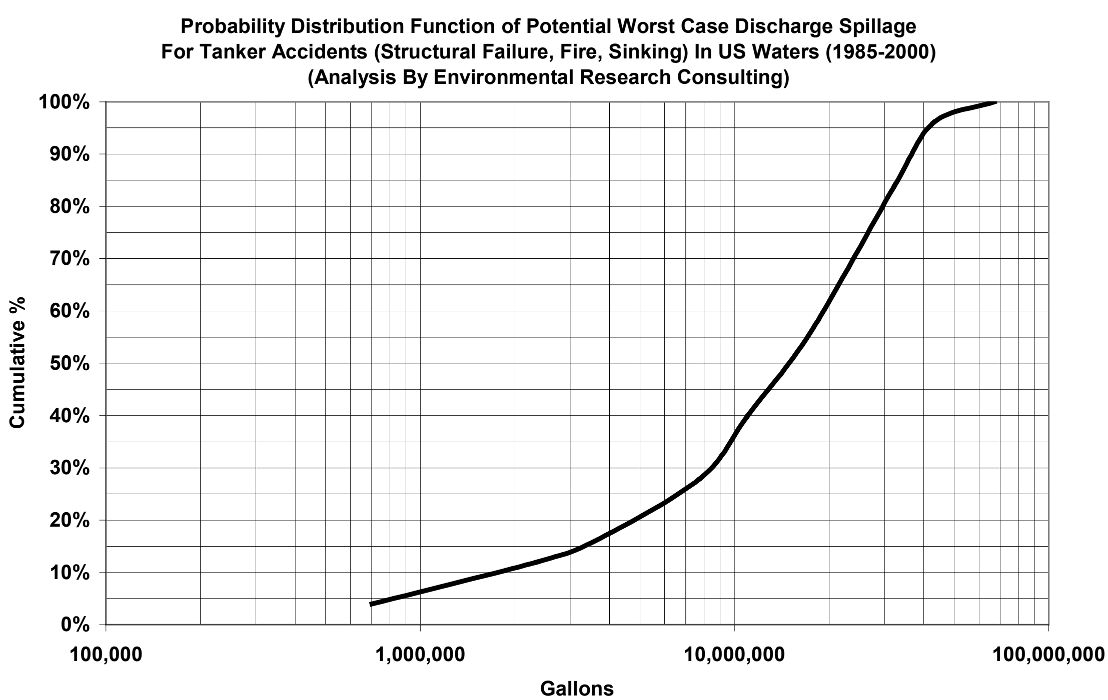
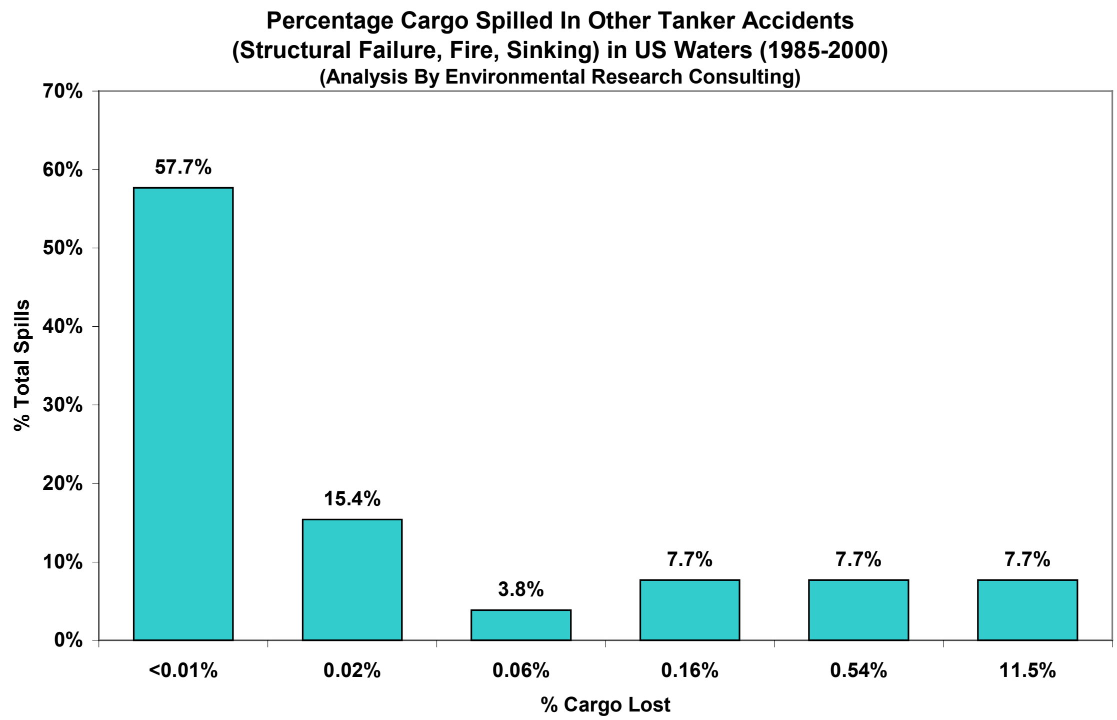


Figure 4.12



4.1.3 US Tanker Spills – Lightering/Loading and Pollution Incidents

Tanker spills in US waters related to lightering, loading, and refueling were analyzed to develop the probability distribution function shown in Figure 4.13. Incidents related to all other causes, such as illegal discharges, bilge washing, and unknown causes, were analyzed to develop the probability distribution function shown in Figures 4.14.

The sizes of these spills relative to spills from accidental causes are shown in Figures 4.15 and 4.16. Spills from lightering, loading, and refueling, as well as other pollution incidents tend to be smaller than those related to accidents.

The percentile spills for tankers, by spill cause, are shown in Table 4.2.

Figure 4.13

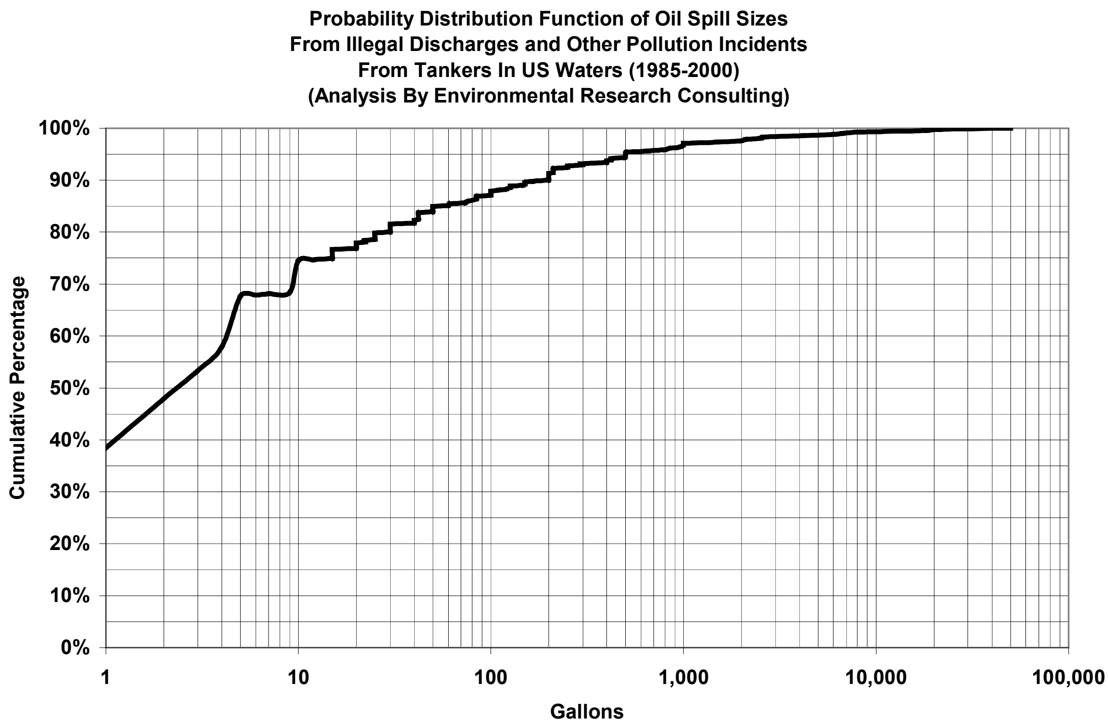


Figure 4.14

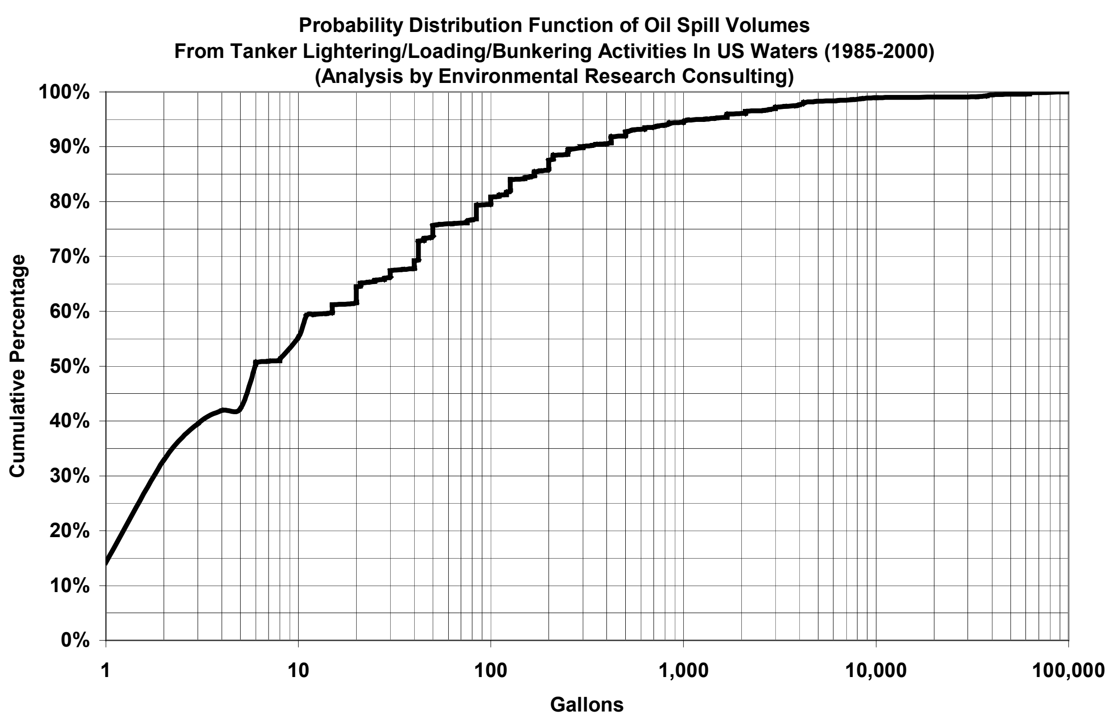


Figure 4.15

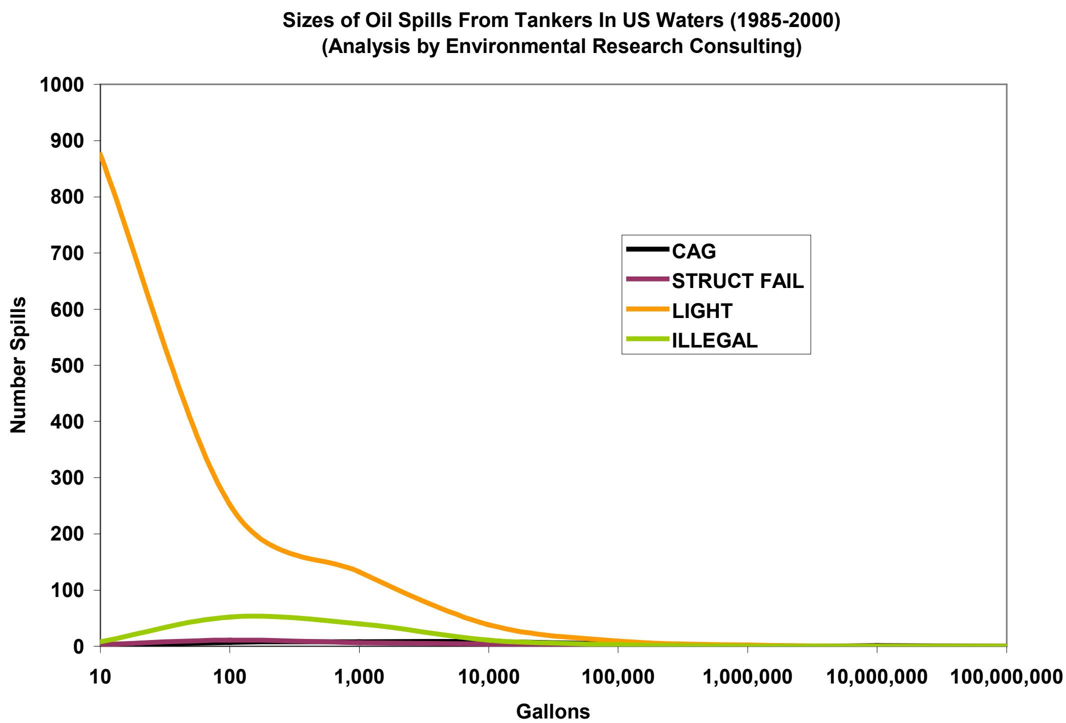


Figure 4.16

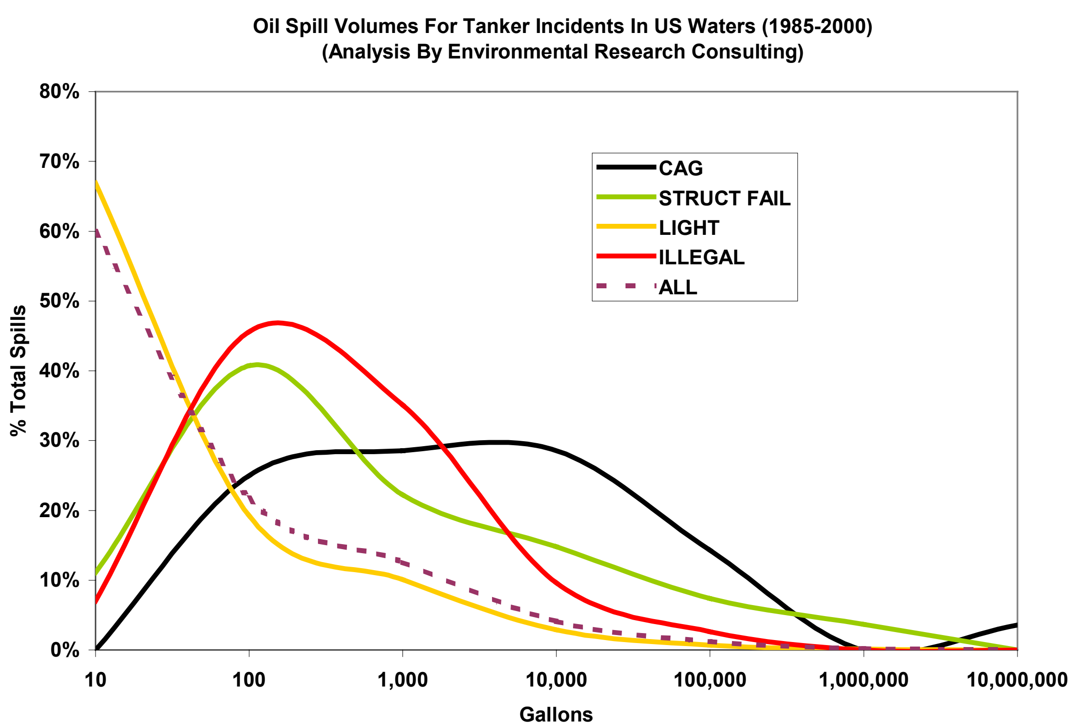


Table 4.2

Actual Vs. Potential Worst-Case Discharge Oil Spillage From Vessels in US Waters (1985-2000)

Spill Type	PERCENTILE SPILLS (gallons) Actual Spill Volumes/Potential Worst-Case Discharge (shaded)[1]						
	10th	25th	50th	75th	90th	95th	Worst Case Discharge
Tankers ALL	50	70	130	600	6,000	11,500	10,500,000
	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Tankers Collis/All/Grou	200	900	6,500	40,000	250,000	275,000	10,500,000
	600,000	6,000,000	8,000,000	15,000,000	25,000,000	40,000,000	80,000,000
Tankers StructFail/Fire	70	120	350	6,000	30,000	200,000	4,000,000
	1,500,000	6,500,000	15,000,000	25,000,000	34,000,000	41,000,000	70,000,000
Tankers Lightering/ Loading[2]	1	2	6	50	300	1,000	100,000
	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Tankers Illegal Discharge[2]	1	1	3	10	200	500	50,000
	n/a	n/a	n/a	n/a	n/a	n/a	n/a

[1]Potential worst-case discharge (complete loss) based on assumption of 80%-full cargo tanks on tankers and barges and 70%-full bunker tanks on freighters and other vessels.

[2]Worst-case discharge is not defined for general pollution incidents, lightering, de-ballasting, cargo loading/unloading, intentional discharges, and unintentional discharges (not related to allisions, groundings, collisions, structural failure, fire or sinking).

Percentile spills are defined as the percentage of spills that are *smaller* than this size, e.g., the 95th percentile spill is that spill size which is larger than 95% of spills (only 5% of spills are larger than this; 95% of spills are smaller than this).

Analysis by Environmental Research Consulting.

4.2. US Barge Spills

4.2.1 US Barge Spills – All Causes

The analysis was repeated for tank barge spills as shown in Figures 4.17 – 4.29 and Table 4.3.

Figure 4.17

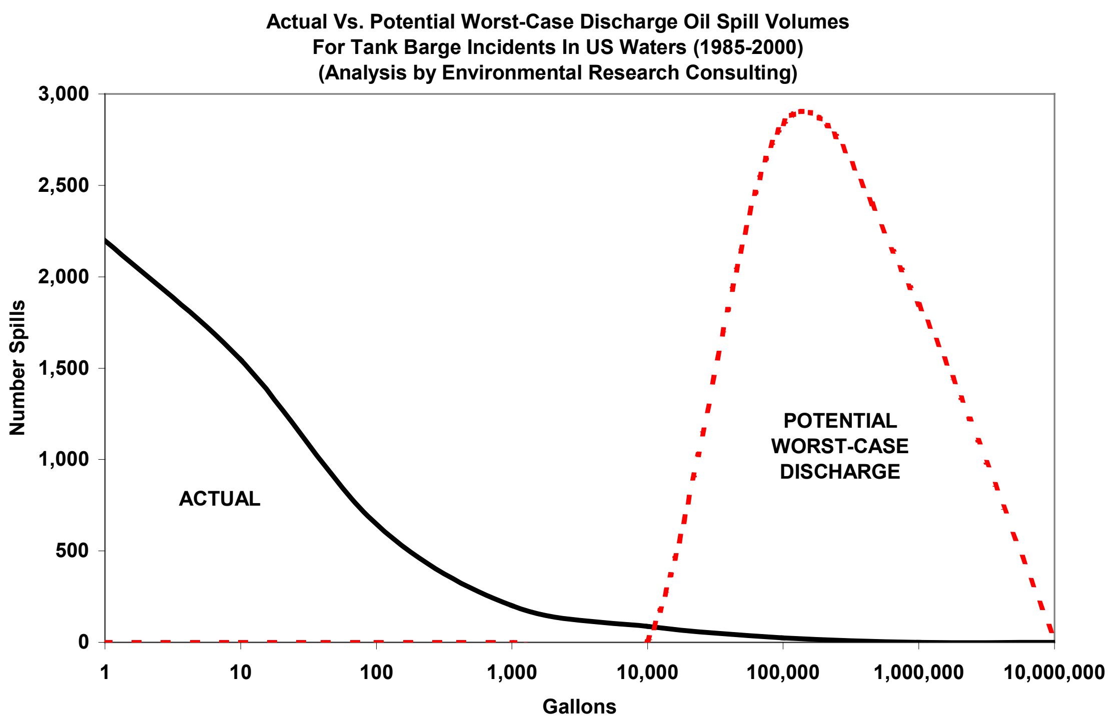


Figure 4.18

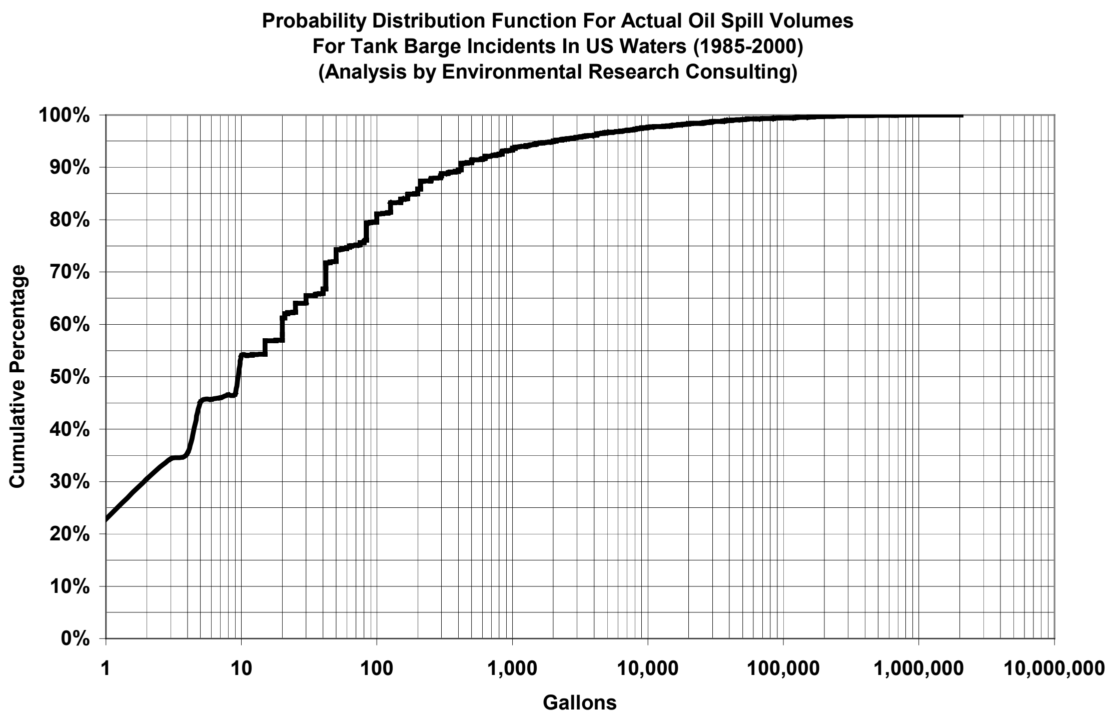
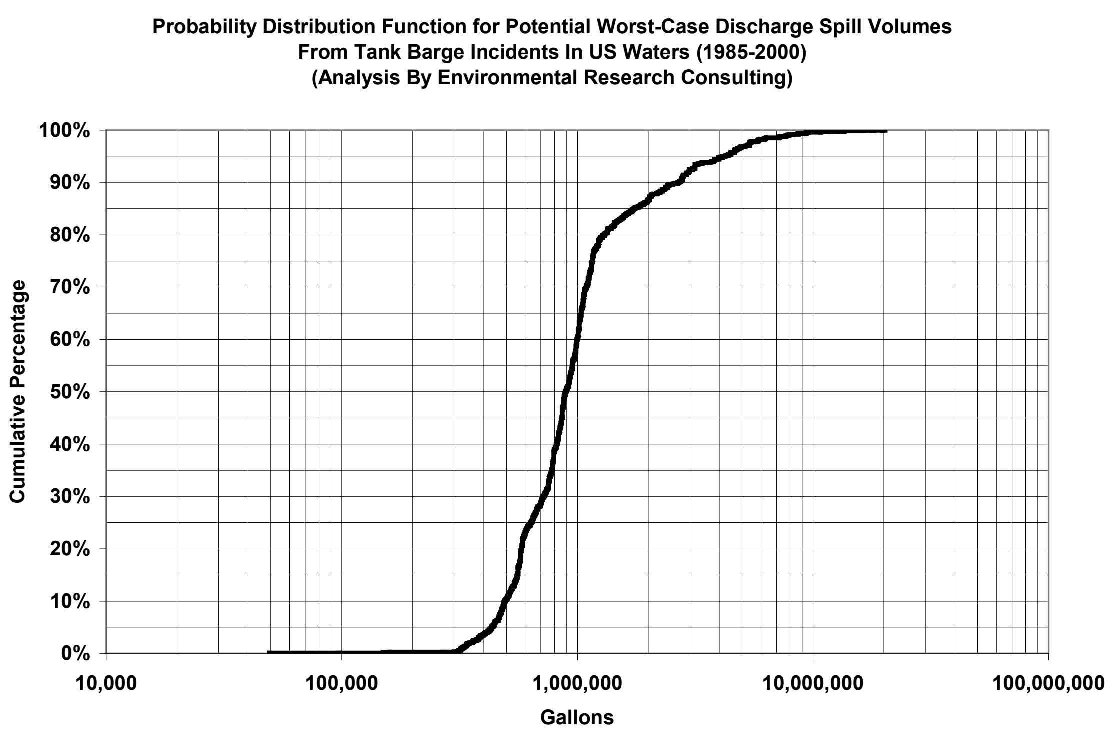


Figure 4.19



4.2.2 US Barge Spills -- Accidents

Figure 4.20

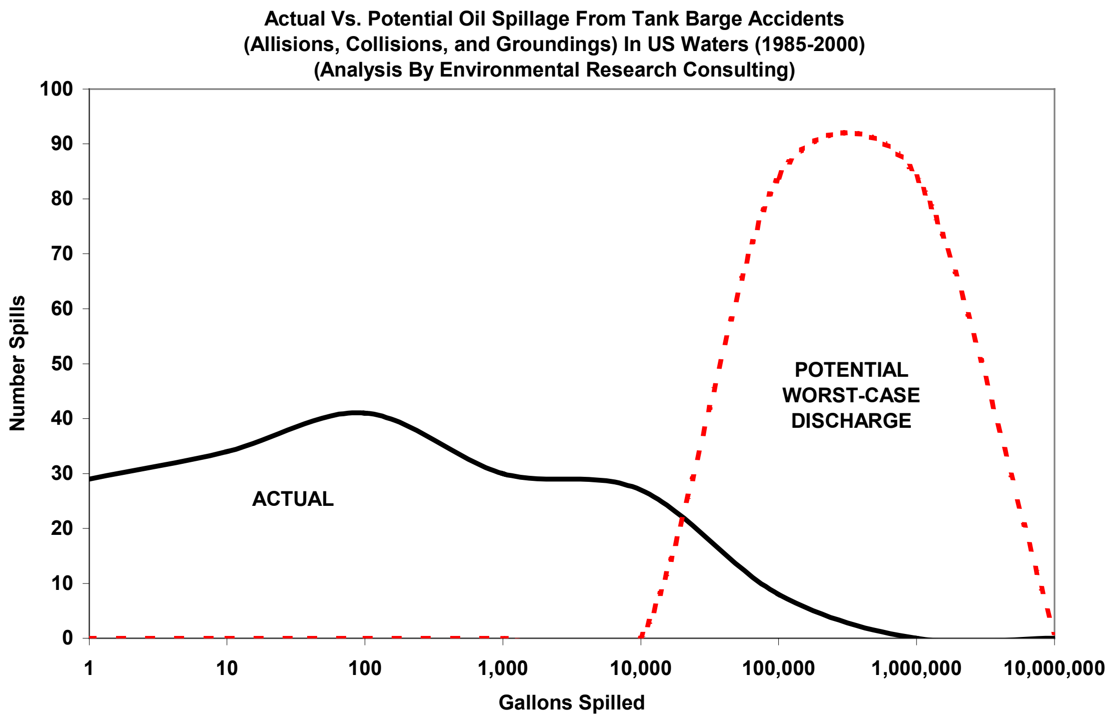


Figure 4.21

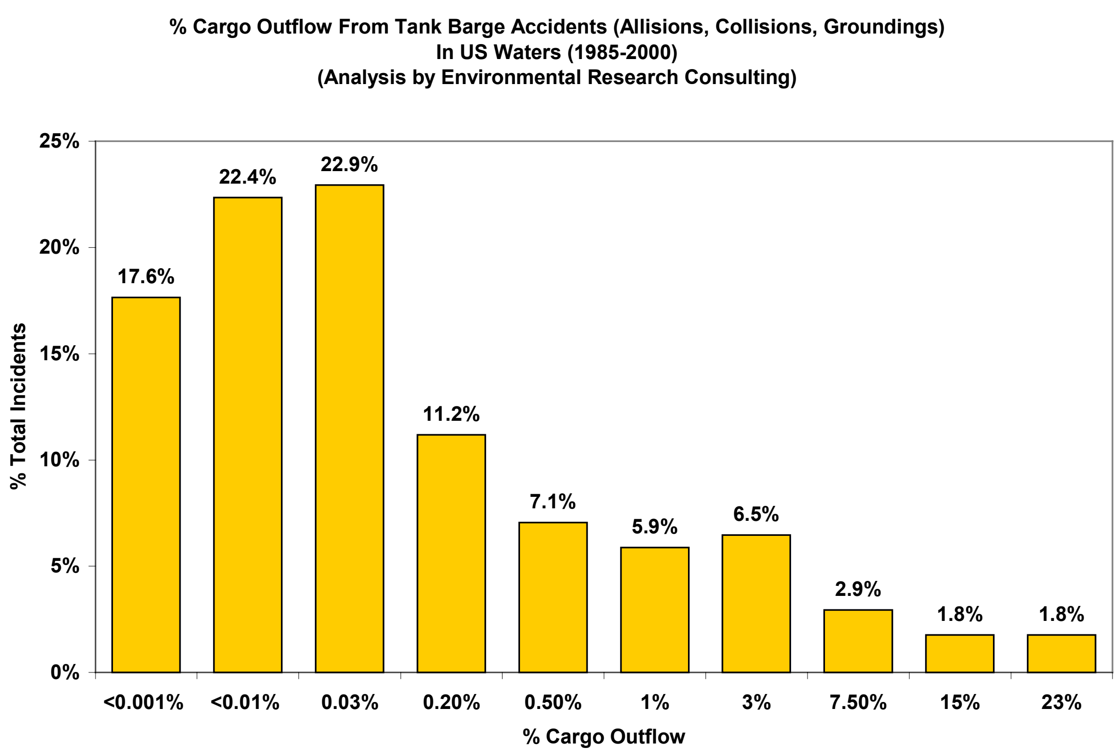


Figure 4.22

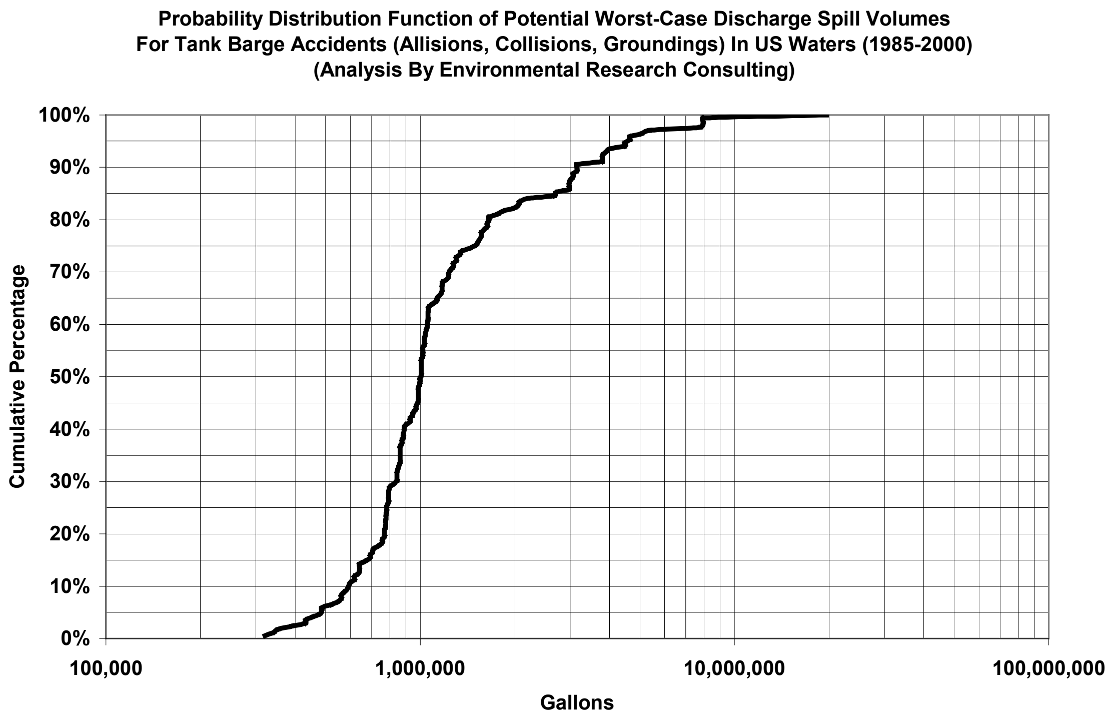


Figure 4.23

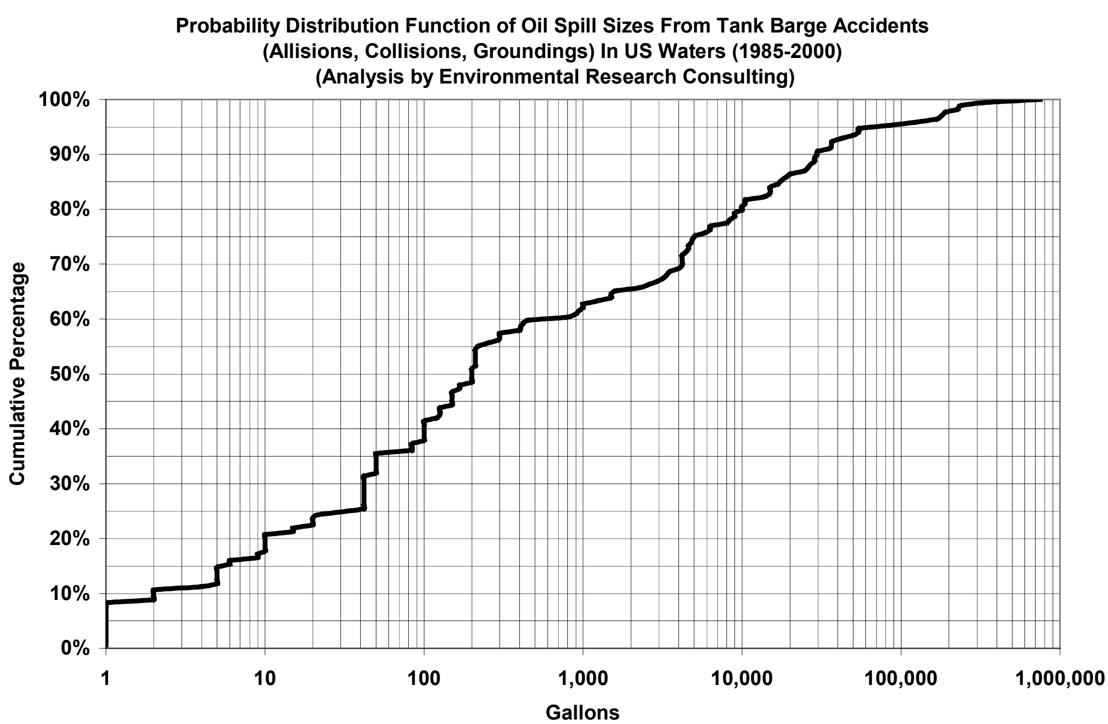


Figure 4.24

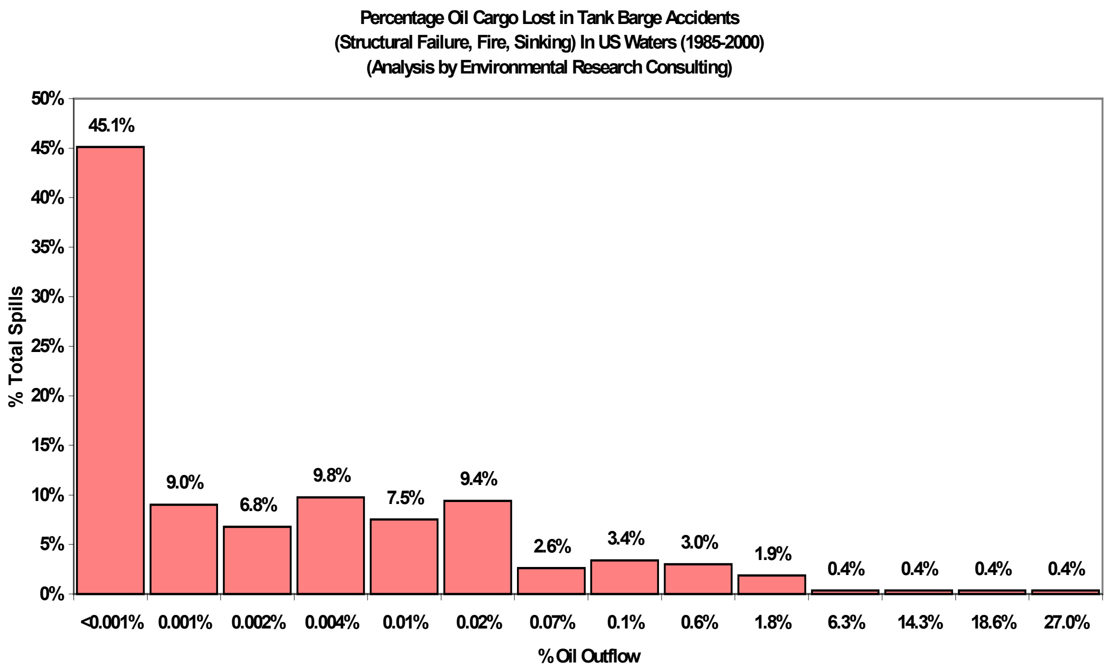


Figure 4.25

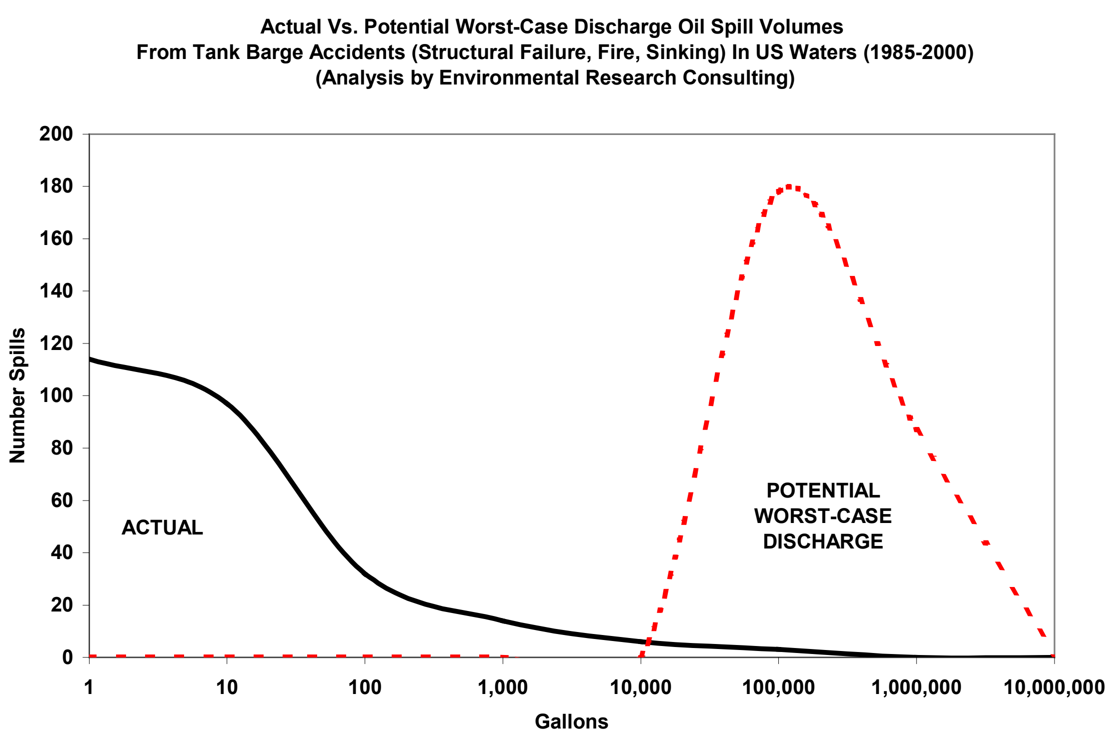


Figure 4.26

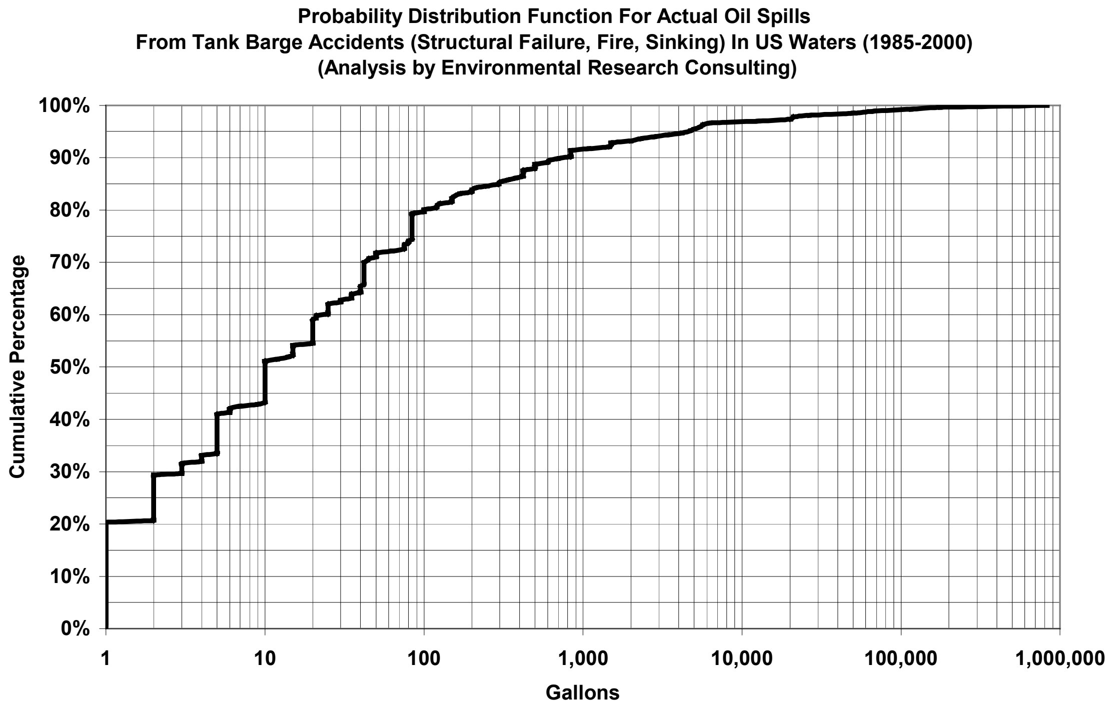
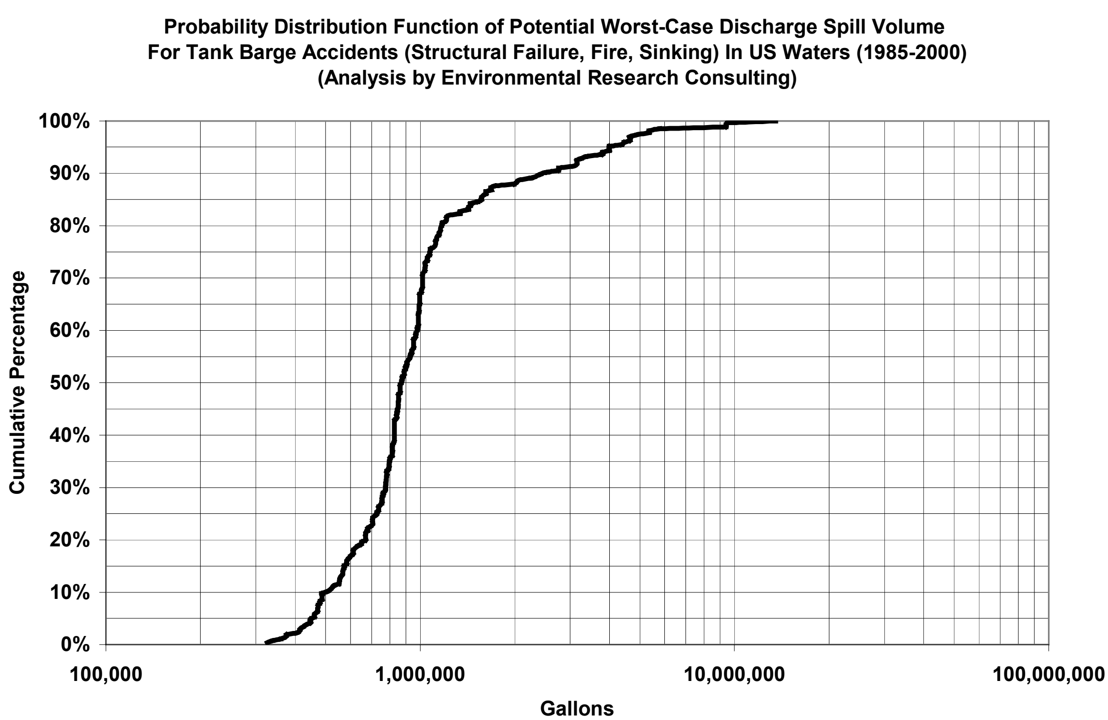


Figure 4.27



4.2.3 US Barge Spills – Lightering/Loading and Pollution Incidents

Figure 4.28

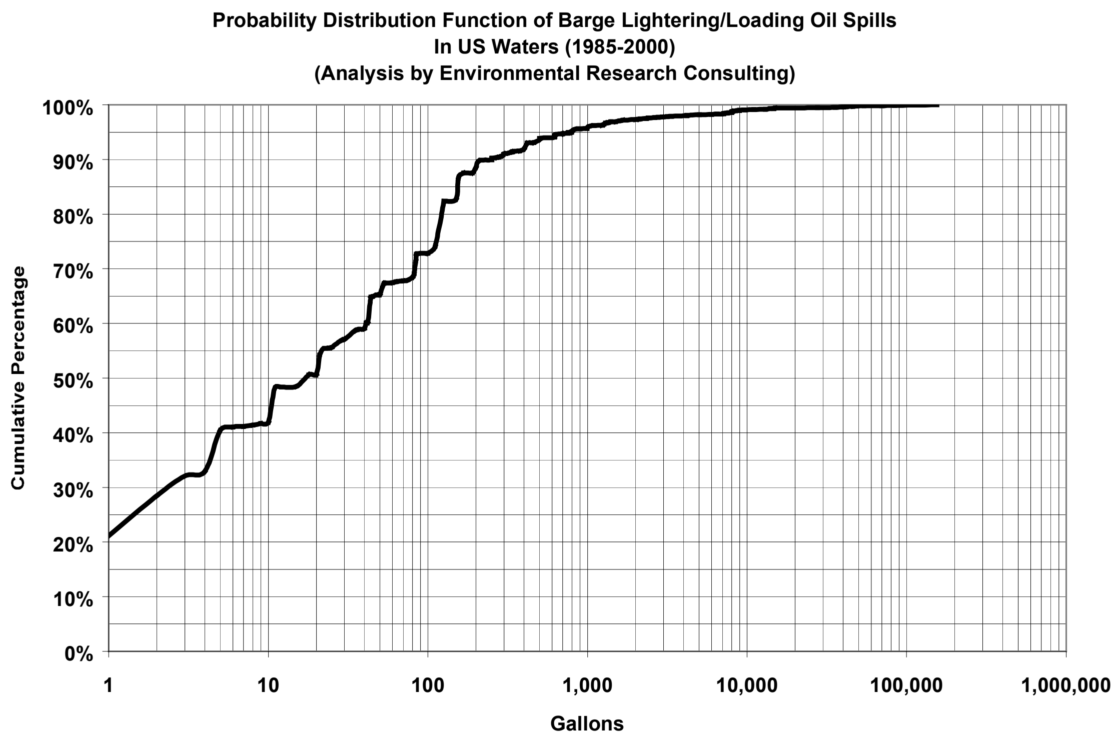


Figure 4.29

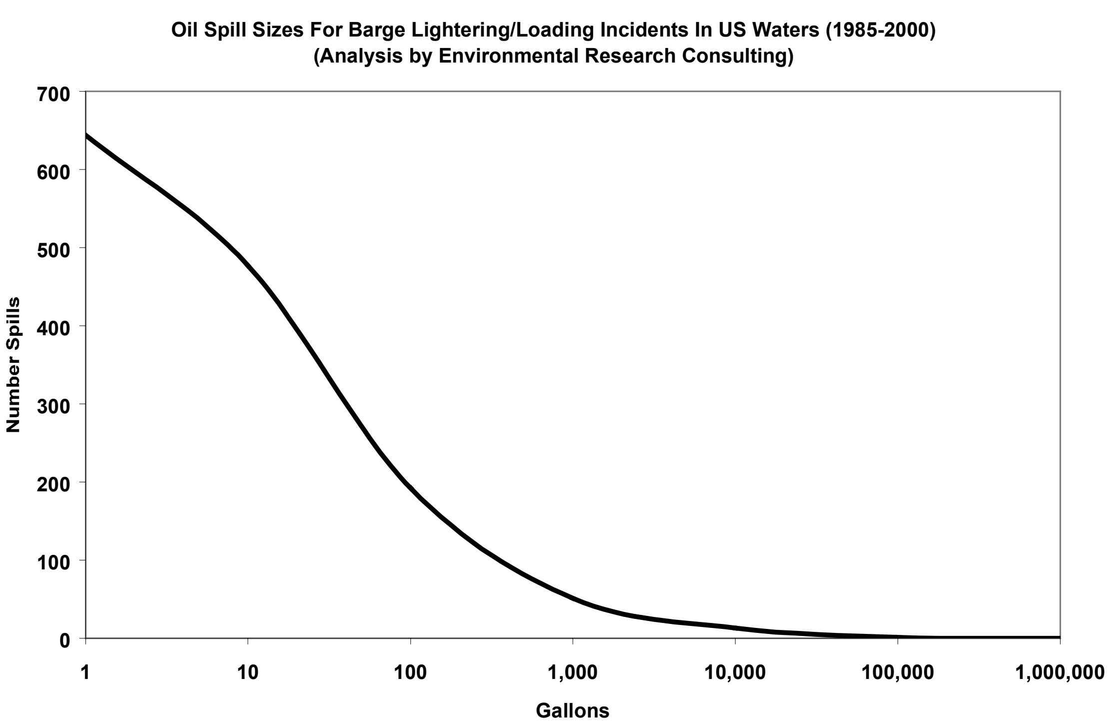


Figure 4.30

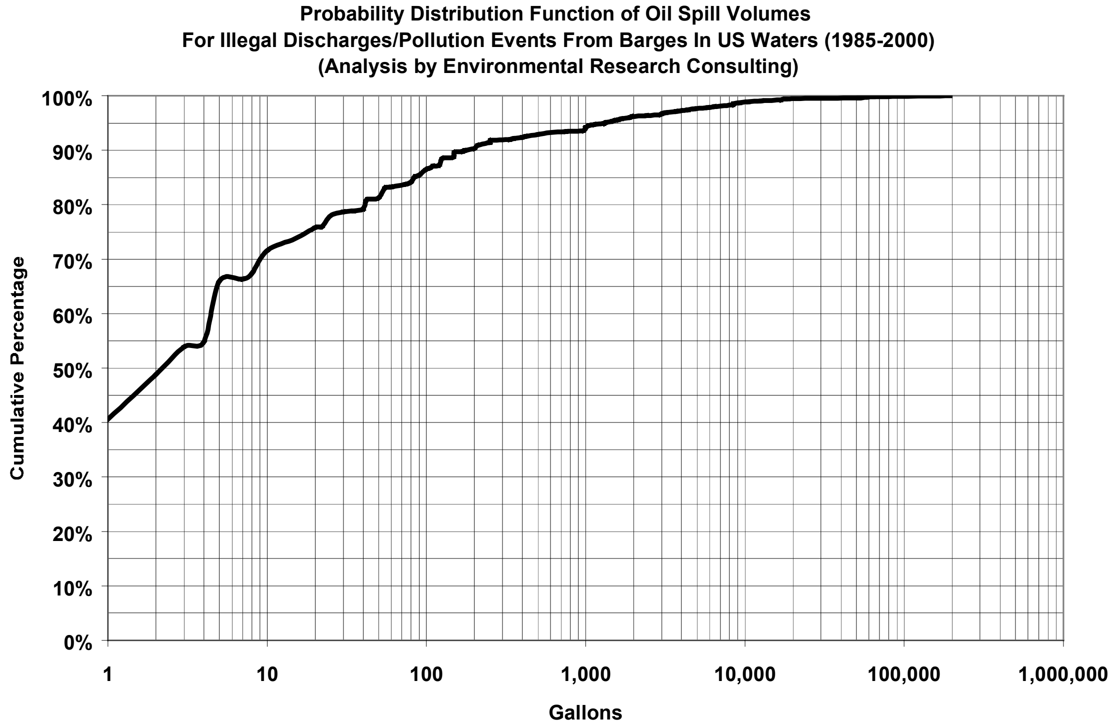


Figure 4.31

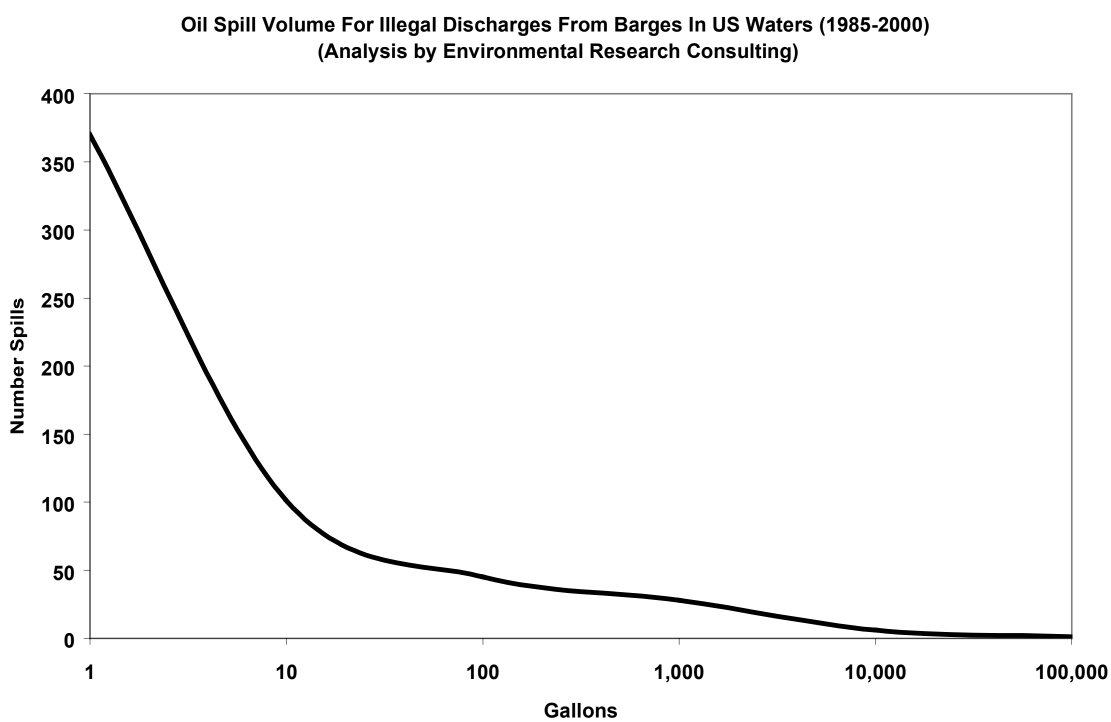


Figure 4.32

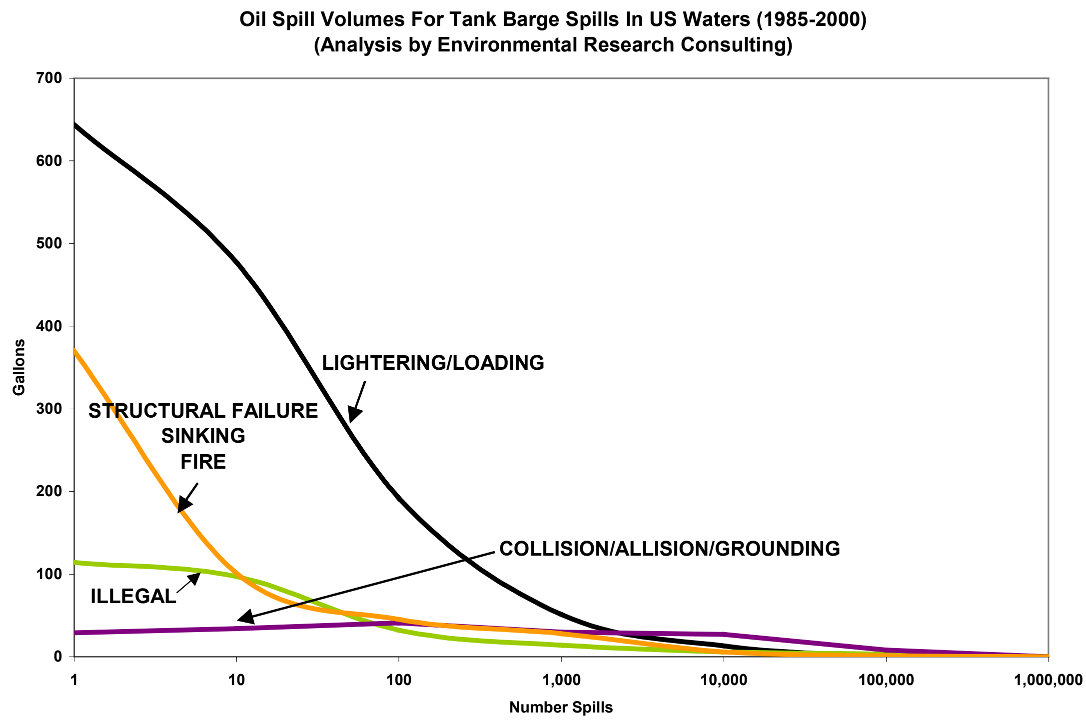


Figure 4.33

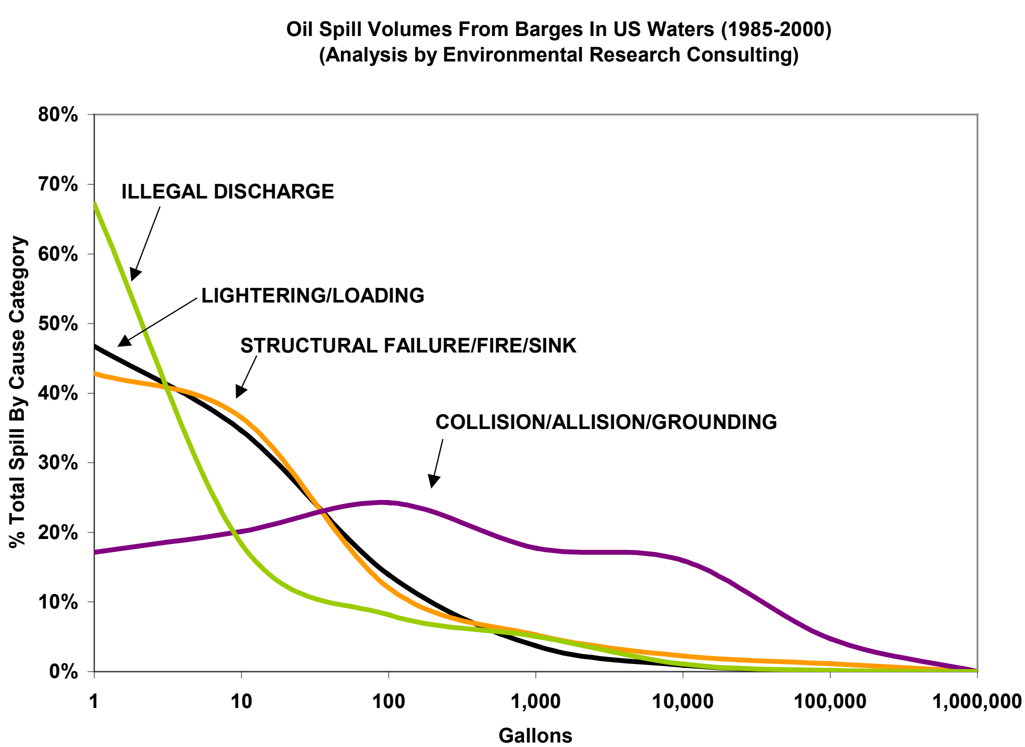


Table 4.3

Actual Vs. Potential Worst-Case Discharge Oil Spillage From Vessels in US Waters (1985-2000)							
Spill Type	**PERCENTILE SPILLS (gallons) Actual Spill Volumes/Potential Worst-Case Discharge (shaded)[1]**						
	10th	**25th**	**50th**	**75th**	**90th**	**95th**	**Worst Case Discharge**
Barges ALL	1	2	10	60	400	2,000	2,000,000
	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Barges Coll/All/Grou	2	30	200	5,000	30,000	60,000	800,000
	600,000	800,000	1,000,000	1,500,000	3,100,000	4,500,000	20,000,000
Barges StructFail/Fire/Sink	1	2	10	85	700	4,000	800,000
	500,000	700,00	850,000	1,100,000	2,300,000	4,000,000	14,000,000
Barges Lightering/Loading[2]	1	2	20	110	300	800	155,000
	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Barges Illegal Discharge[2]	1	1	2	20	200	1,000	195,000
	n/a	n/a	n/a	n/a	n/a	n/a	n/a

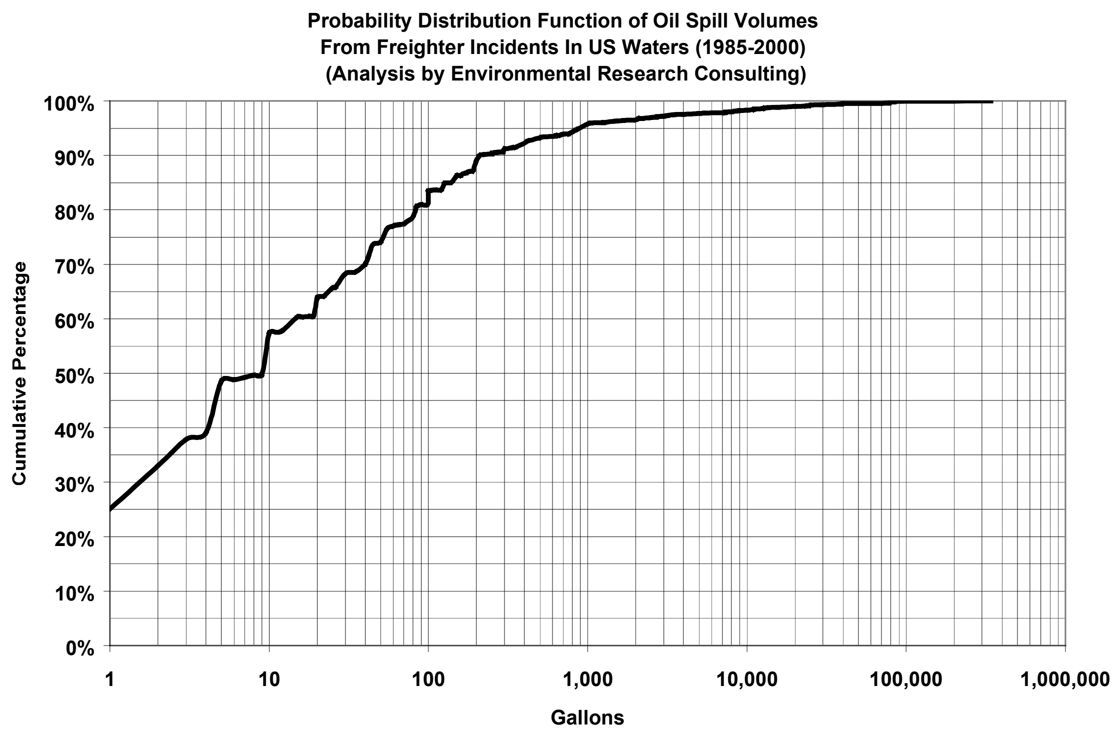
[1]Potential worst-case discharge (complete loss) based on assumption of 80%-full cargo tanks on tankers and barges and 70%-full bunker tanks on freighters and other vessels.
[2]Worst-case discharge is not defined for general pollution incidents, lightering, de-ballasting, cargo loading/unloading, intentional discharges, and unintentional discharges (not related to allisions, groundings, collisions, structural failure, fire or sinking).
Percentile spills are defined as the percentage of spills that are *smaller* than this size, e.g., the 95th percentile spill is that spill size which is larger than 95% of spills (only 5% of spills are larger than this; 95% of spills are smaller than this).
Analysis by Environmental Research Consulting.

4.3 US Freight Vessel (>300 GRT) Spills

4.3.1 US Freight Vessel (>300 GRT) Spills – All Causes

Spills from freight vessels over 300 GRT were analyzed as shown in Figures 4.34 – 4.47.

Figure 4.34



4.3.2 US Freight Vessel (>300 GRT) Spills -- Accidents

Figure 4.35

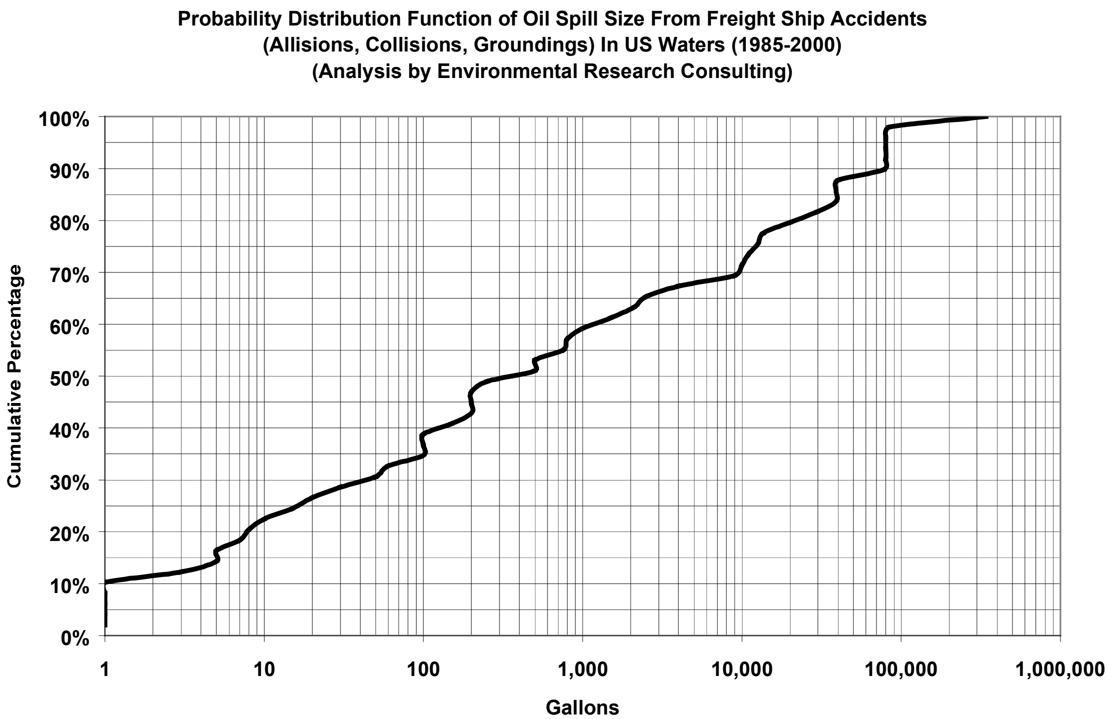


Figure 4.36

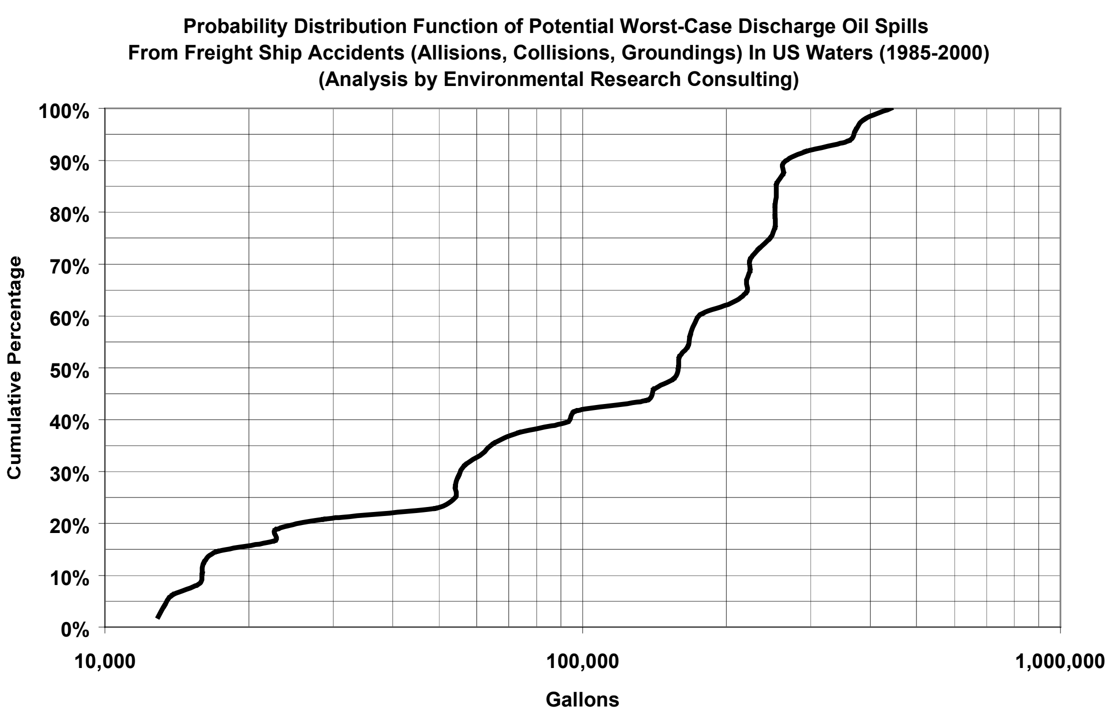


Figure 4.37

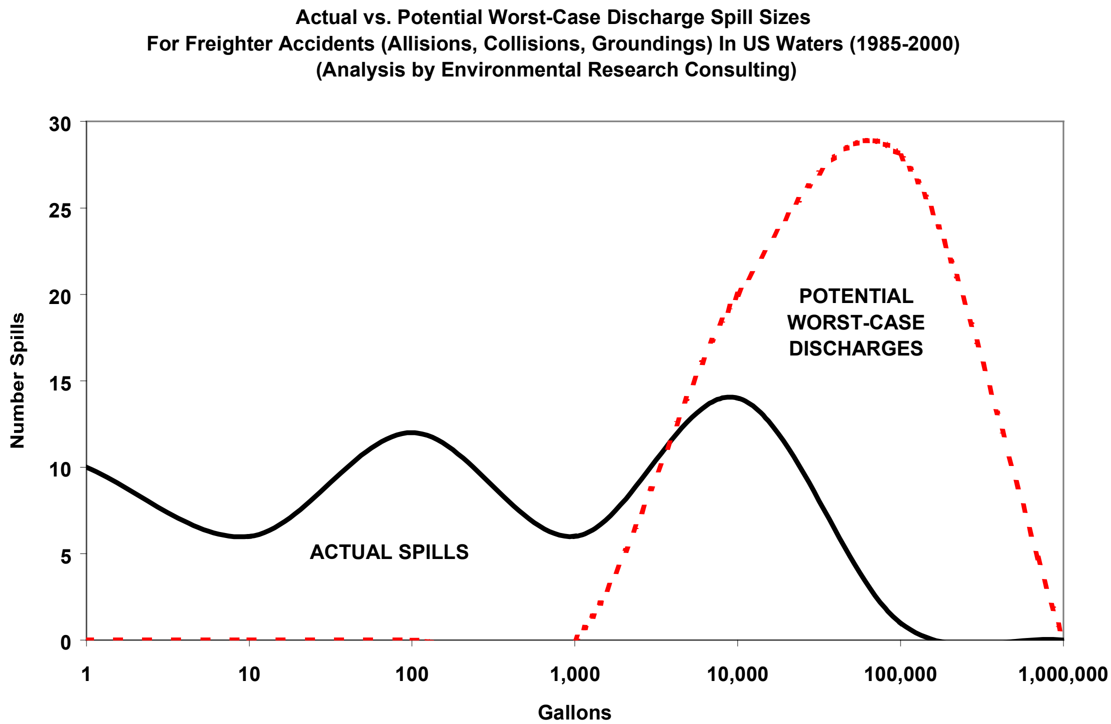


Figure 4.38

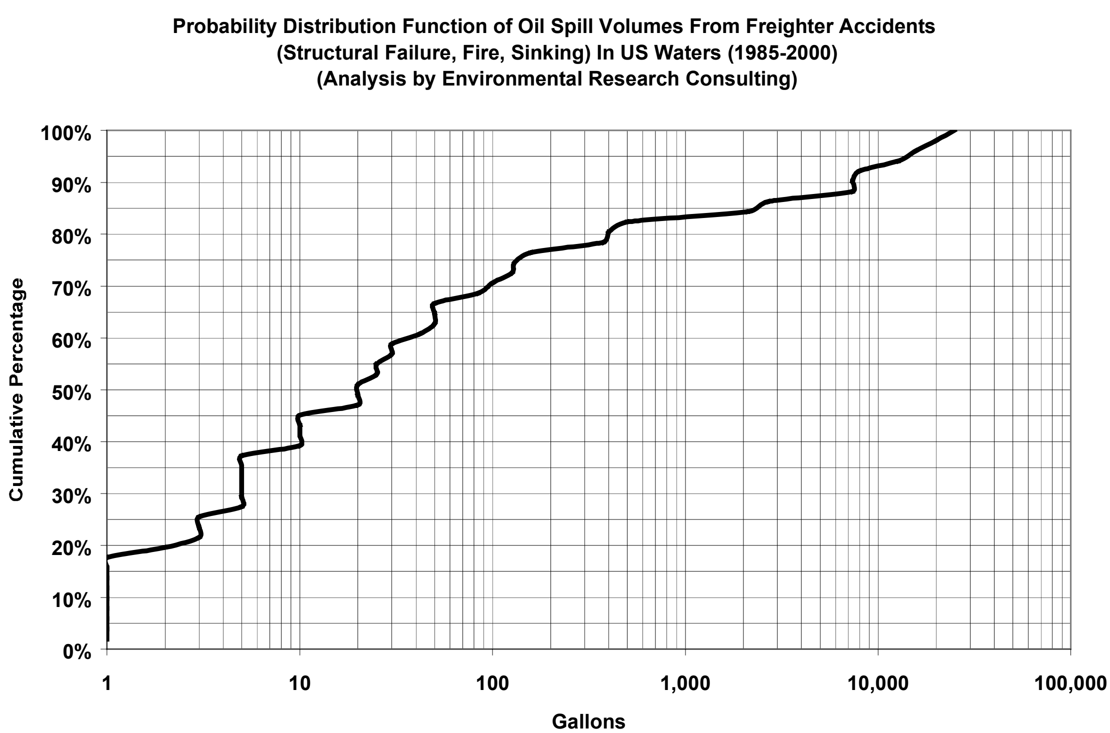


Figure 4.39

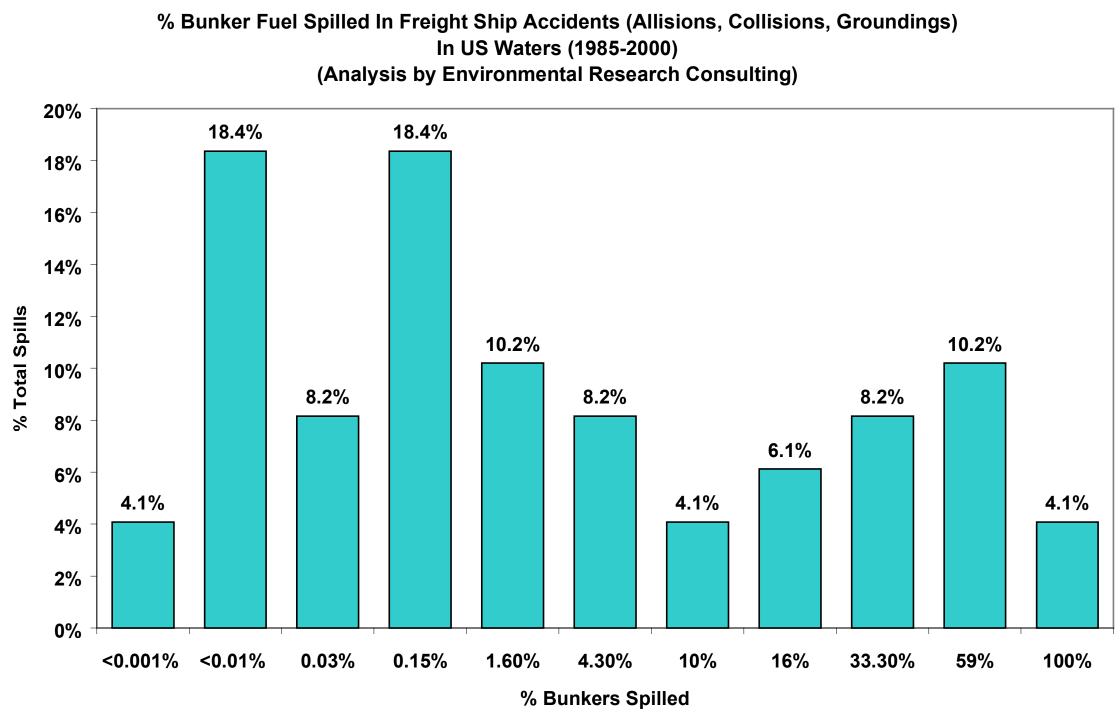


Figure 4.40

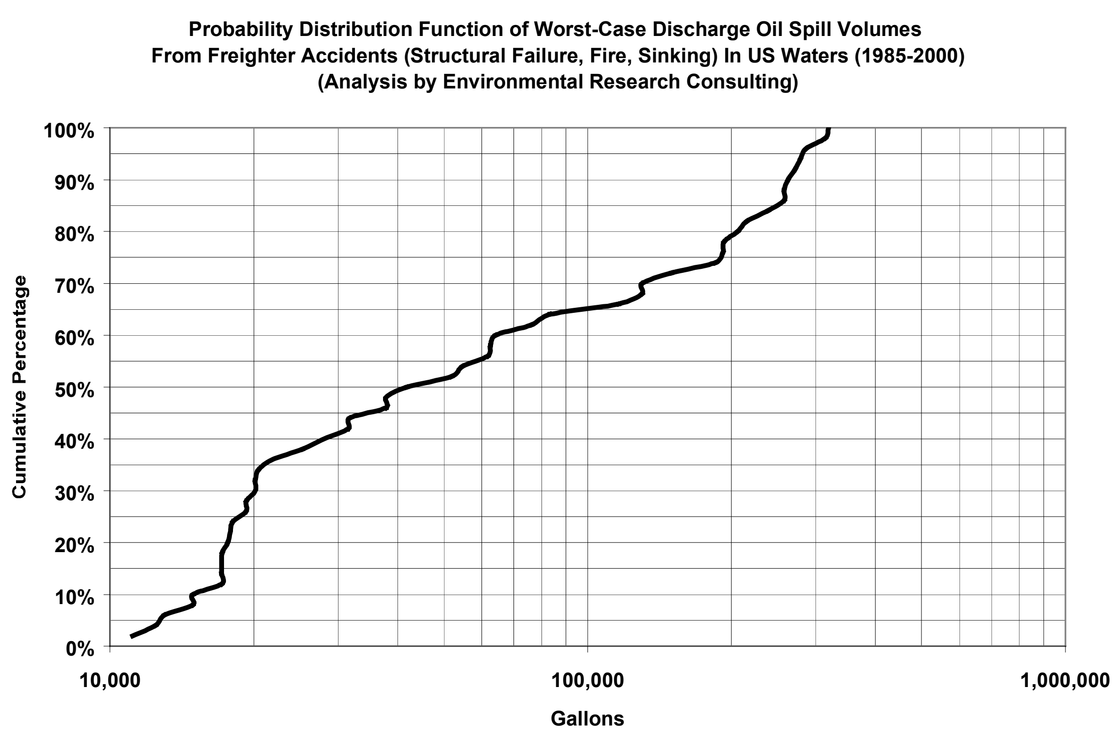


Figure 4.41

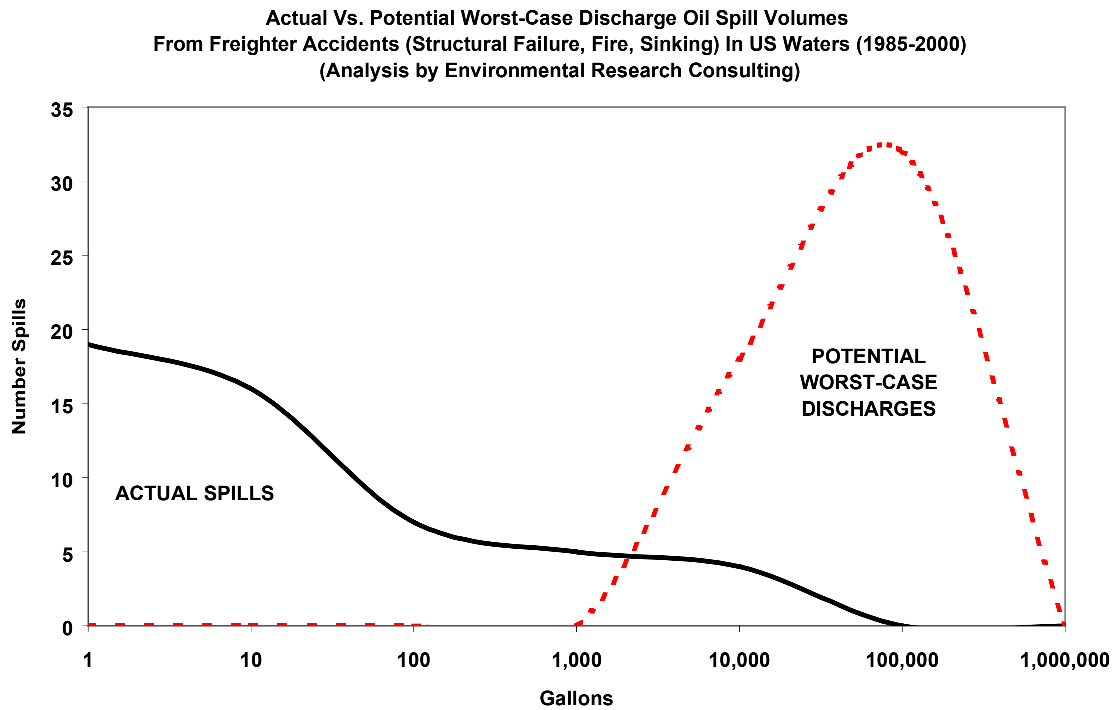
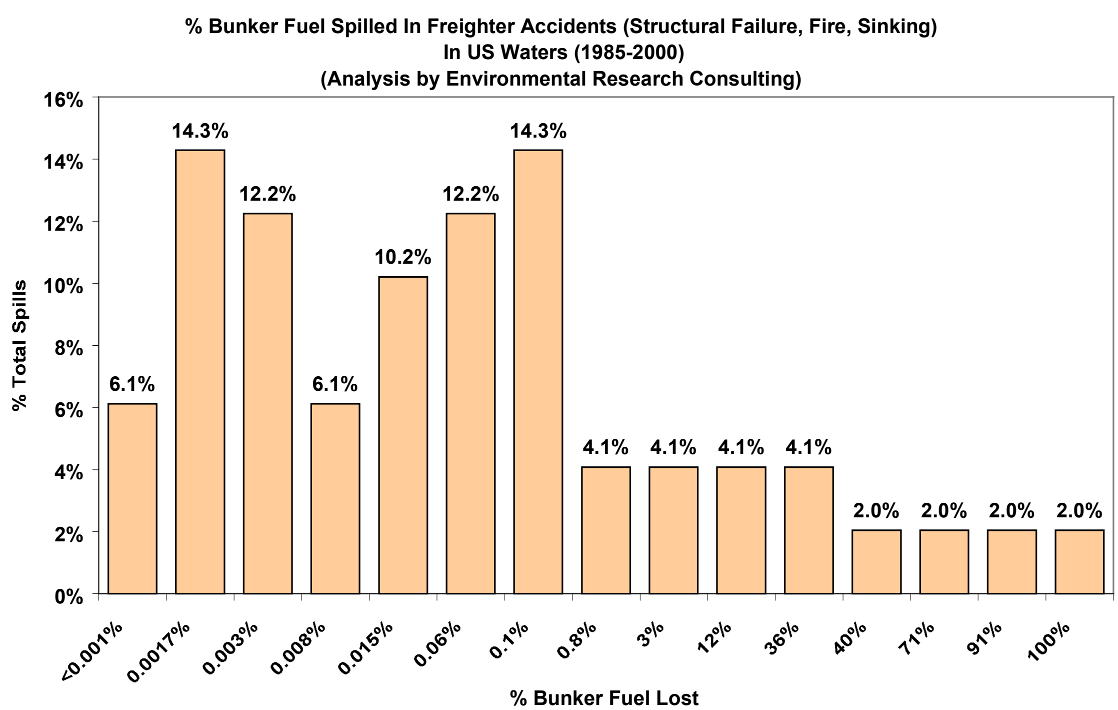


Figure 4.42



4.3.3 US Freight Vessel (> 300 GRT) Spills – Illegal Discharge/Pollution/Bunkering

Figure 4.43

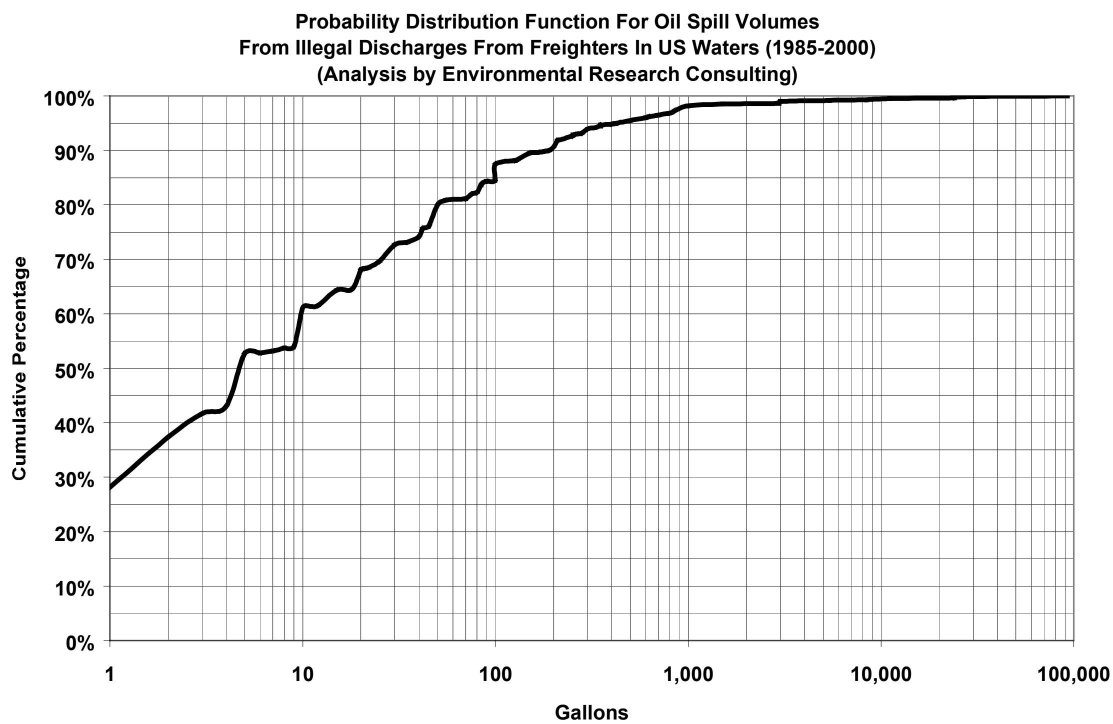


Figure 4.44

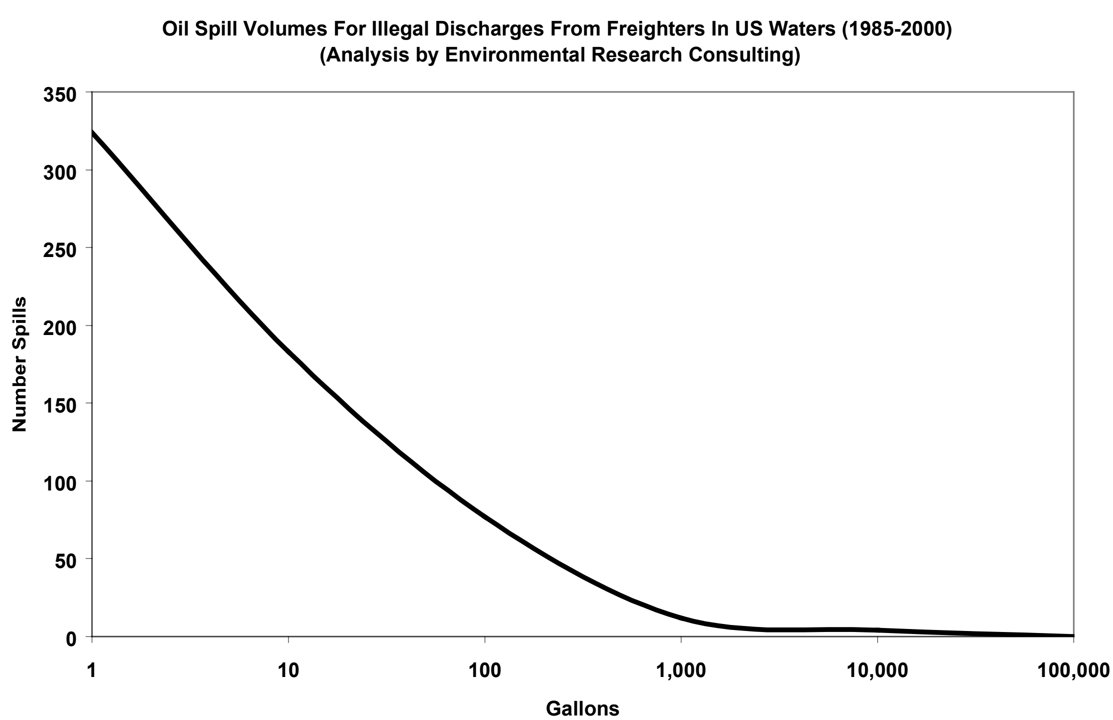


Figure 4.45

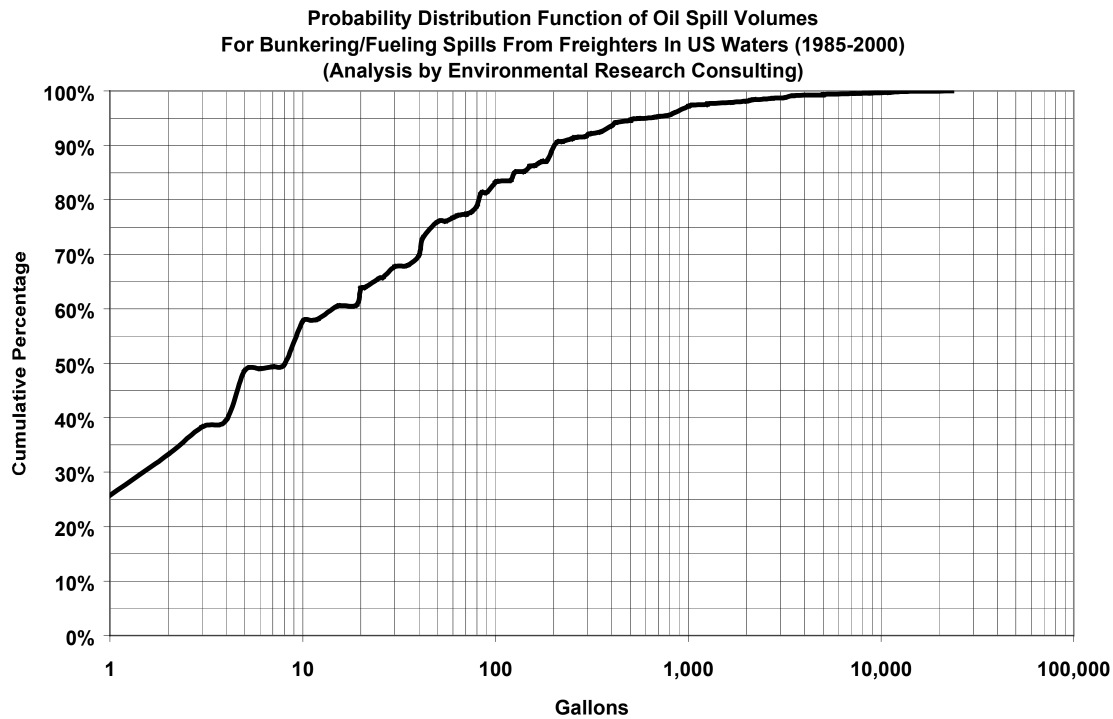


Figure 4.46

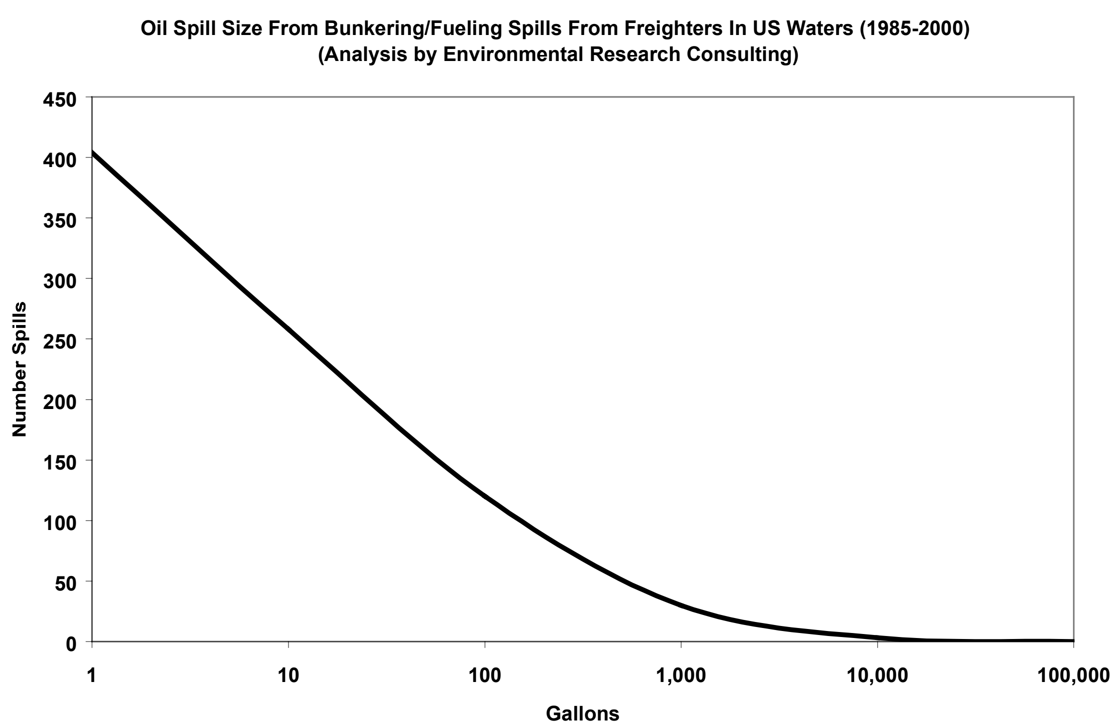


Figure 4.46

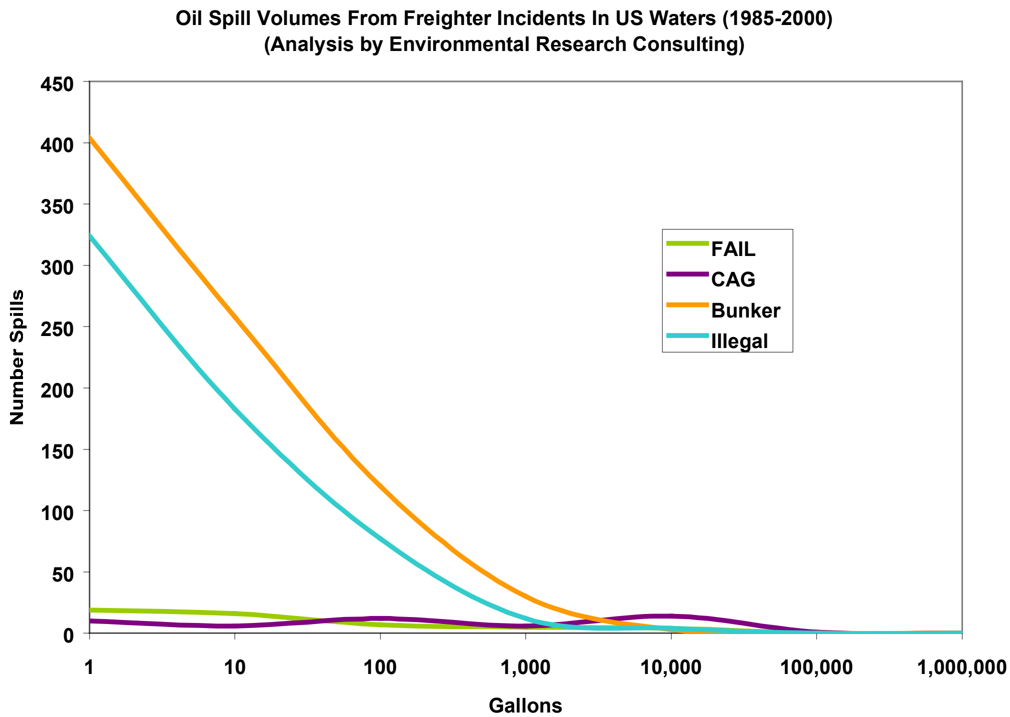


Figure 4.47

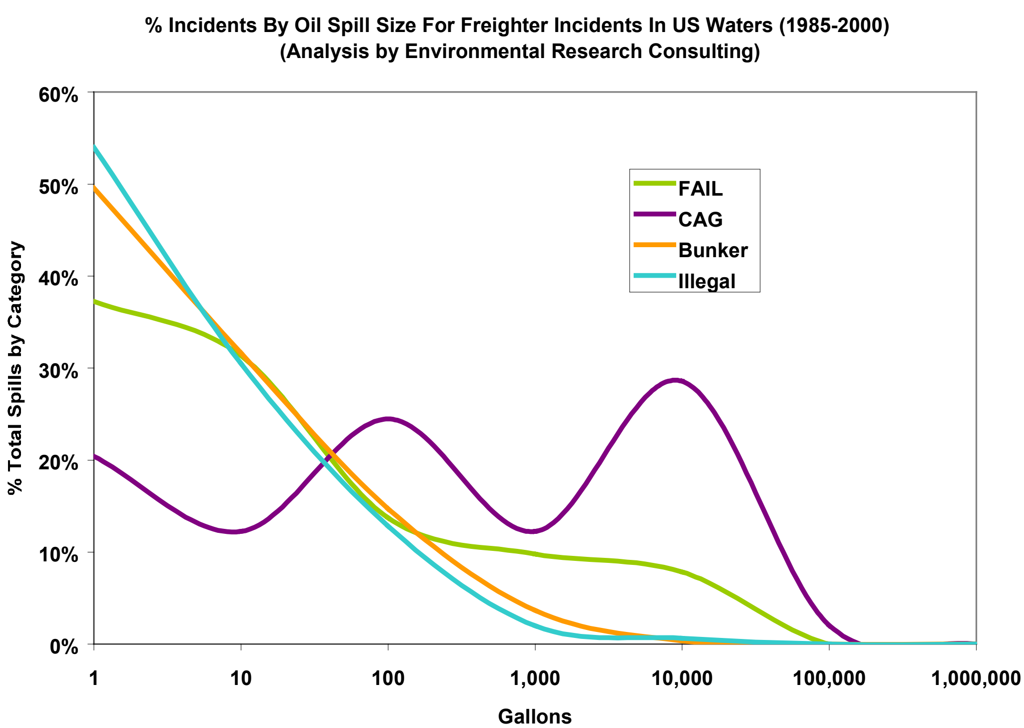


Table 4.4

Actual Vs. Potential Worst-Case Discharge Oil Spillage From Vessels in US Waters (1985-2000)							
Spill Type	PERCENTILE SPILLS (gallons) Actual Spill Volumes/Potential Worst-Case Discharge (shaded)[1]						
	10th	25th	50th	75th	90th	95th	Worst Case Discharge
Freighters ALL	1	1	8	50	200	1,000	350,000
	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Freighters Coll/All/Grou	1	15	300	10,100	80,000	82,000	350,000
	15,000	52,000	120,000	240,000	270,000	370,000	440,000
Freighters StructFail/Fire/Sink	1	3	20	150	7,500	12,000	25,000
	12,000	18,000	40,000	180,000	220,000	280,000	320,000
Freighters Bunkering[2]	1	1	8	50	200	600	23,300
	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Freighters Illegal Discharges	1	1	5	40	300	400	93,000
	n/a	n/a	n/a	n/a	n/a	n/a	n/a

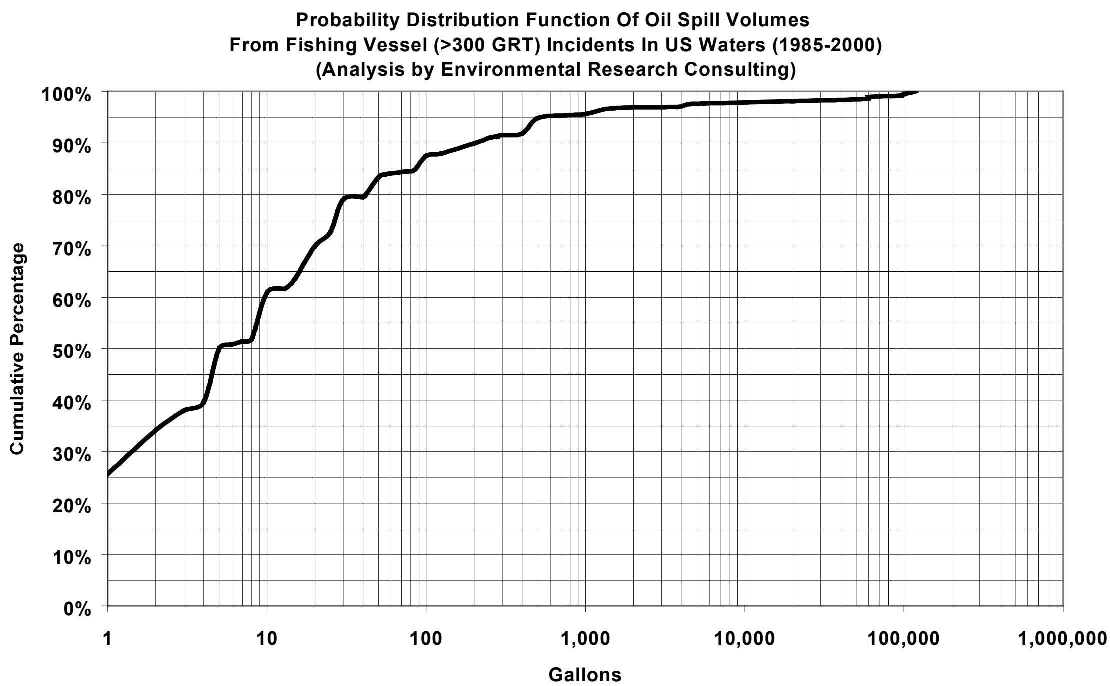
[1]Potential worst-case discharge (complete loss) based on assumption of 80%-full cargo tanks on tankers and barges and 70%-full bunker tanks on freighters and other vessels.
[2]Worst-case discharge is not defined for general pollution incidents, lightering, de-ballasting, cargo loading/unloading, intentional discharges, and unintentional discharges (not related to allisions, groundings, collisions, structural failure, fire or sinking).
Percentile spills are defined as the percentage of spills that are *smaller* than this size, e.g., the 95th percentile spill is that spill size which is larger than 95% of spills (only 5% of spills are larger than this; 95% of spills are smaller than this).
Analysis by Environmental Research Consulting.

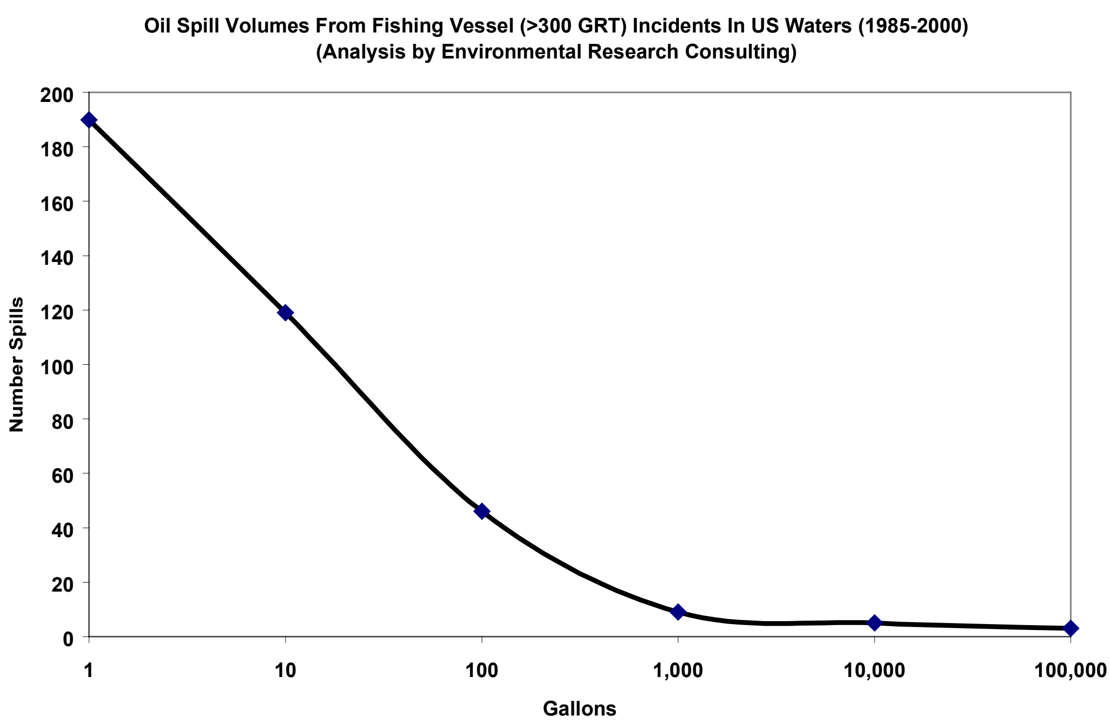
4.4 US Fishing Vessel (>300 GRT) Spills

4.4.1. US Fishing Vessel (>300 GRT) Spills – All Causes

Fishing vessel (>300 GRT) spills were analyzed as shown in Figures 4.48 4.54.

Figure 4.48 and 4.49





4.4.2 US Fishing Vessels (>300 GRT) -- Accidents

Figure 4.50

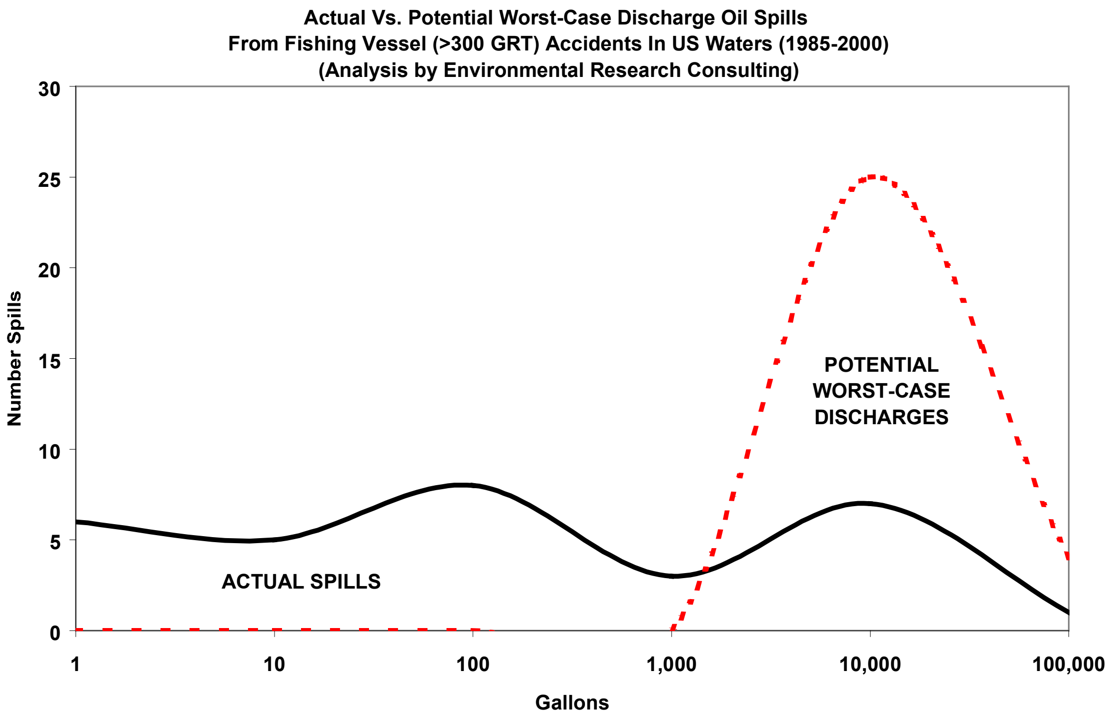


Figure 4.51

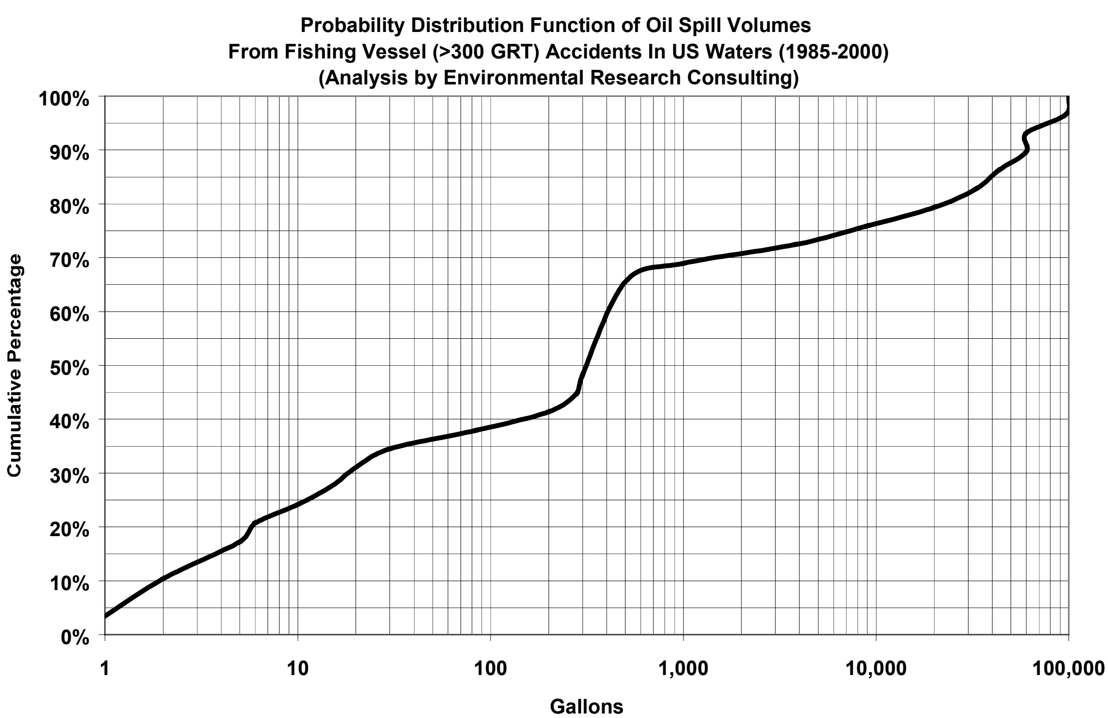


Figure 4.52

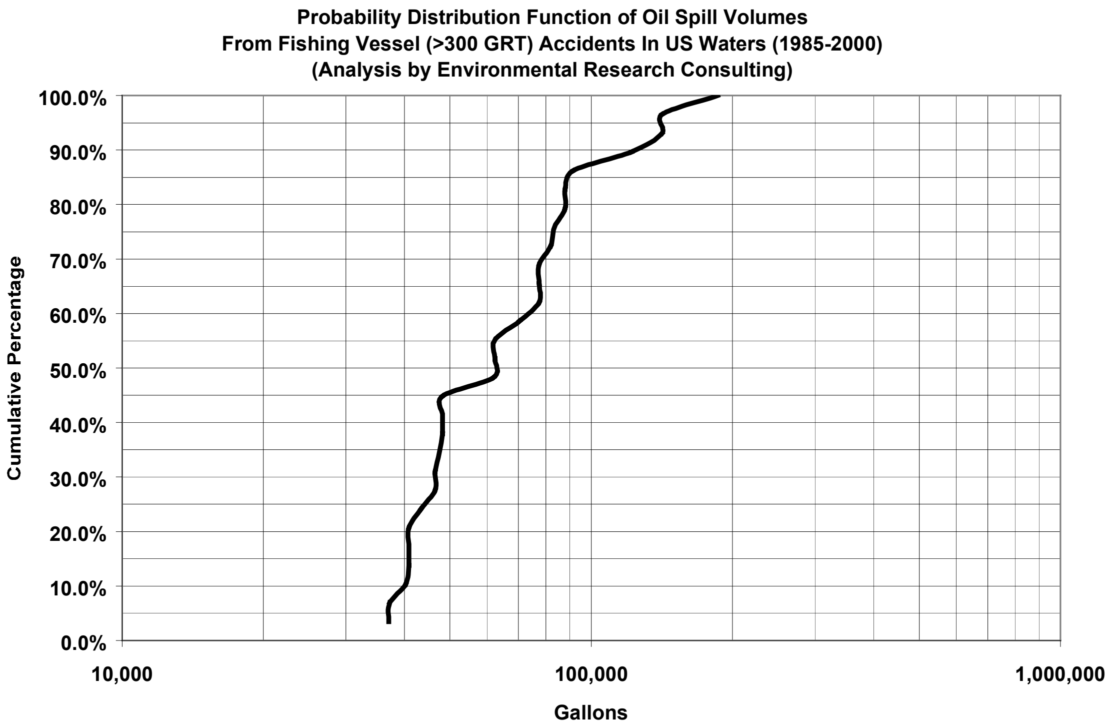
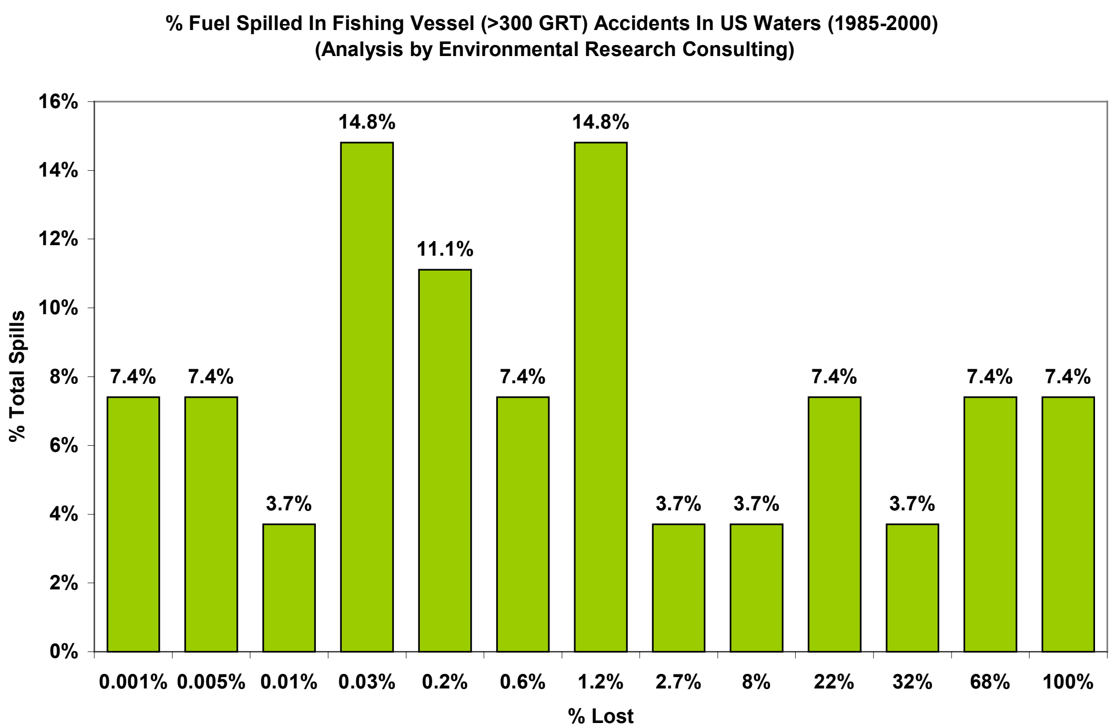


Figure 4.53



4.4.2 US Fishing Vessel (>300 GRT) Spills – Illegal Discharges/Pollution/Fueling

Figure 4.53

Probability Distribution Function For Oil Spill Volumes
From Illegal Discharges/Pollution Events From Fishing Vessels (>300 GRT)
In US Waters (1985-2000)
(Analysis by Environmental Research Consulting)

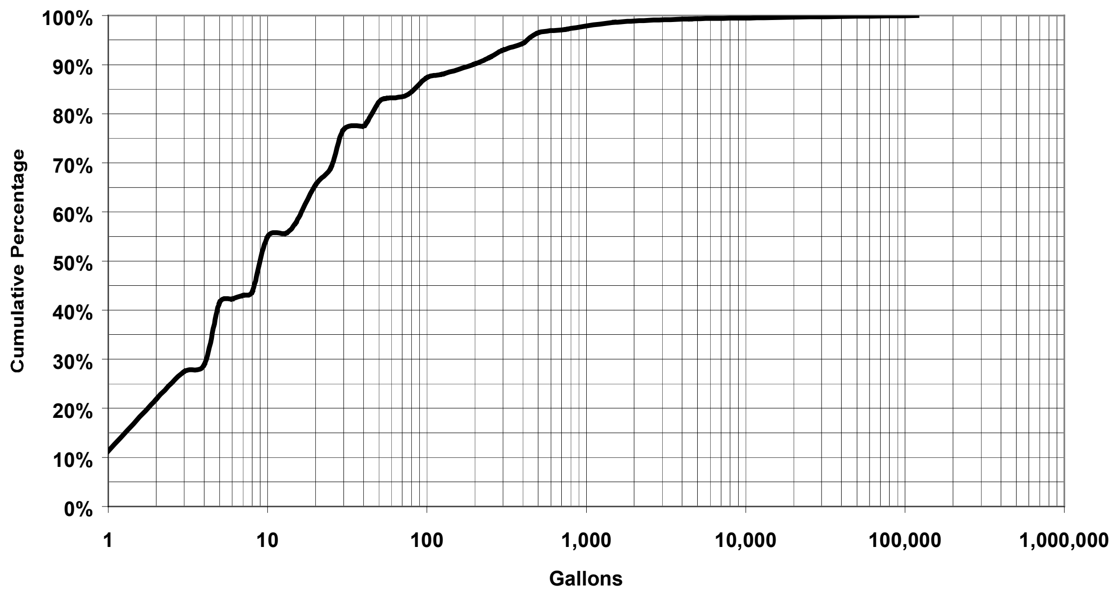


Figure 4.54

Probability Distribution Function of Oil Spill Volumes
From Fishing Vessel (>300 GRT) Fueling Accidents In US Waters (1985-2000)
(Analysis by Environmental Research Consulting)

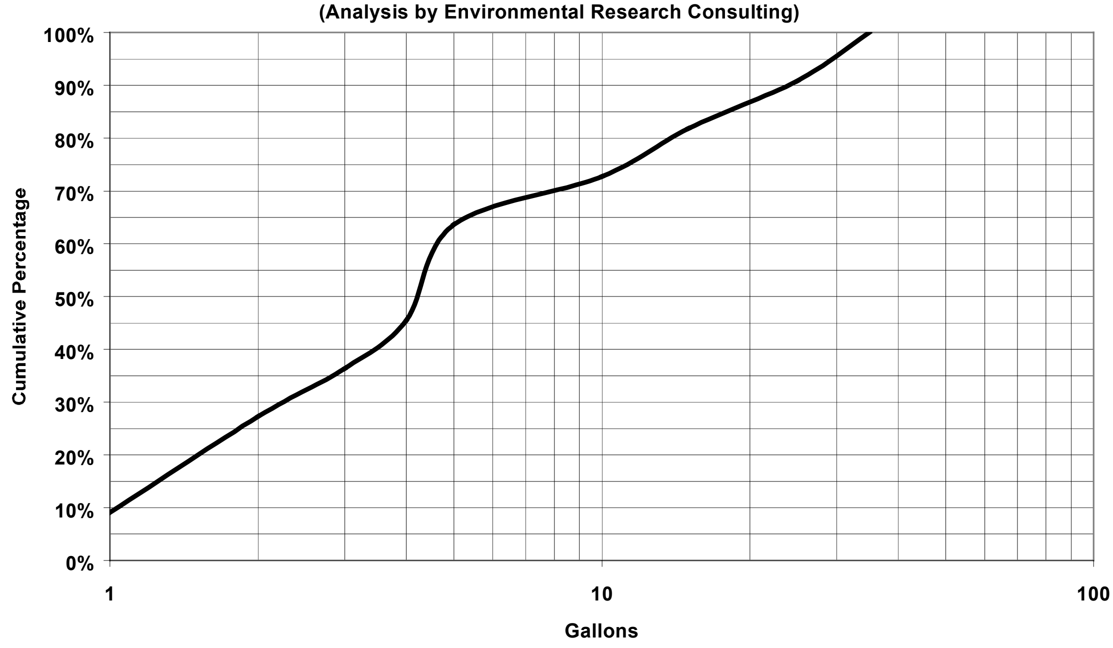


Table 4.5

Actual Vs. Potential Worst-Case Discharge Oil Spillage From Vessels in US Waters (1985-2000)							
Spill Type	PERCENTILE SPILLS (gallons) Actual Spill Volumes/Potential Worst-Case Discharge (shaded)[1]						
	10th	25th	50th	75th	90th	95th	Worst Case Discharge
Fishing Vessels ALL	1	2	5	25	200	500	120,000
	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Fishing Vessels Accidents	2	10	300	7,000	60,000	80,000	100,000
	40,000	45,000	65,000	85,000	110,000	140,000	190,000
Fishing Vessels Fueling[2]	1	2	4	10	25	30	35
	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Fishing Vessels Illegal Discharge[2]	1	3	9	30	200	400	120,000
	n/a	n/a	n/a	n/a	n/a	n/a	n/a

[1]Potential worst-case discharge (complete loss) based on assumption of 80%-full cargo tanks on tankers and barges and 70%-full bunker tanks on freighters and other vessels.
[2]Worst-case discharge is not defined for general pollution incidents, lightering, de-ballasting, cargo loading/unloading, intentional discharges, and unintentional discharges (not related to allisions, groundings, collisions, structural failure, fire or sinking).
Percentile spills are defined as the percentage of spills that are *smaller* than this size, e.g., the 95th percentile spill is that spill size which is larger than 95% of spills (only 5% of spills are larger than this; 95% of spills are smaller than this).
Analysis by Environmental Research Consulting.

4.5 US Passenger Vessel (>300 GRT) Spills

4.5.1 US Passenger Vessel (>300 GRT) Spills – All Causes

An analysis of passenger vessel (>300 GRT) spills is shown in Figures 4.55-4.64.

Figure 4.55

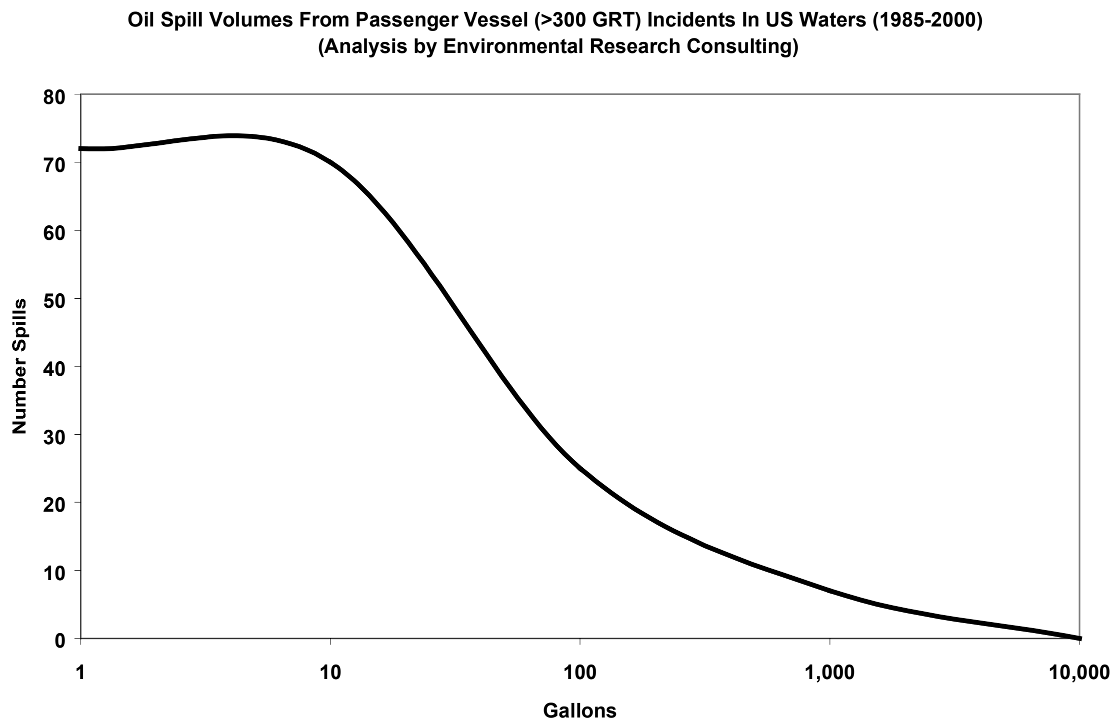
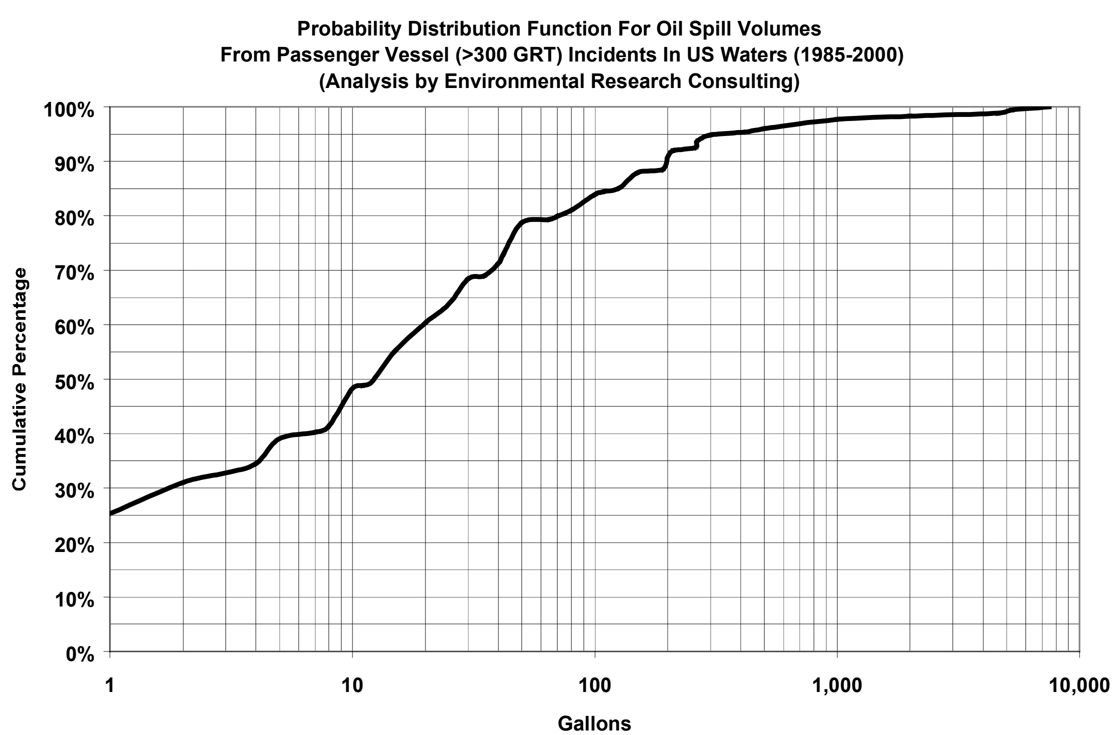


Figure 4.56



4.5.2 US Passenger Vessel (>300 GRT) Spills – Accidents

Figure 4.57

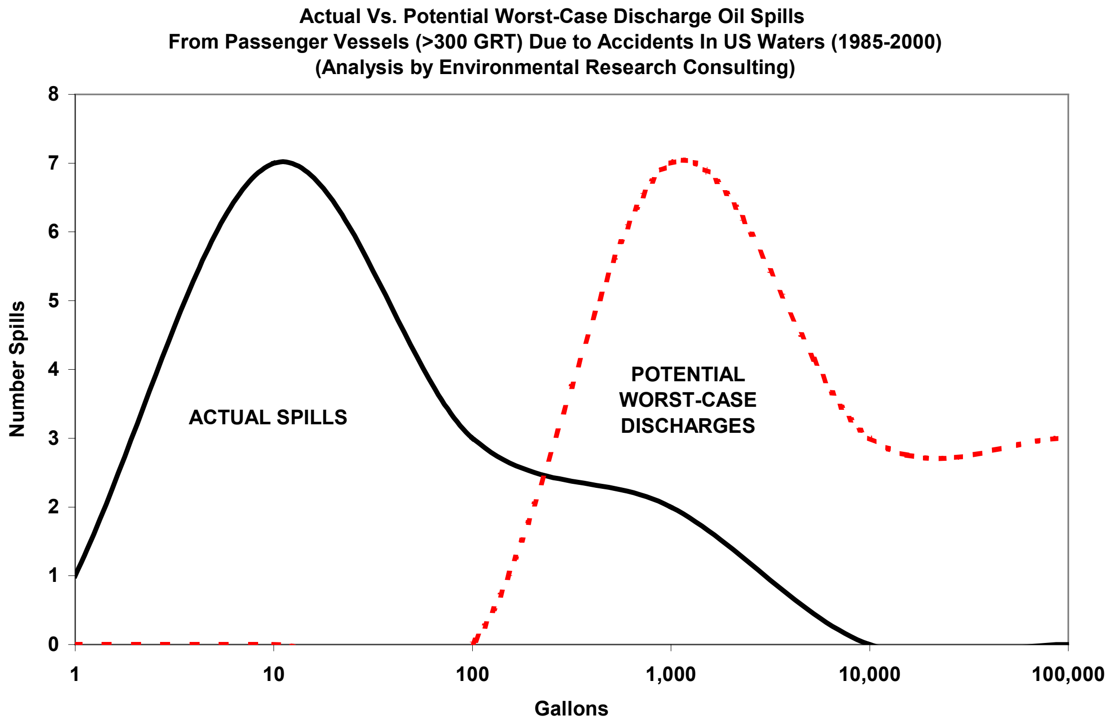


Figure 4.58

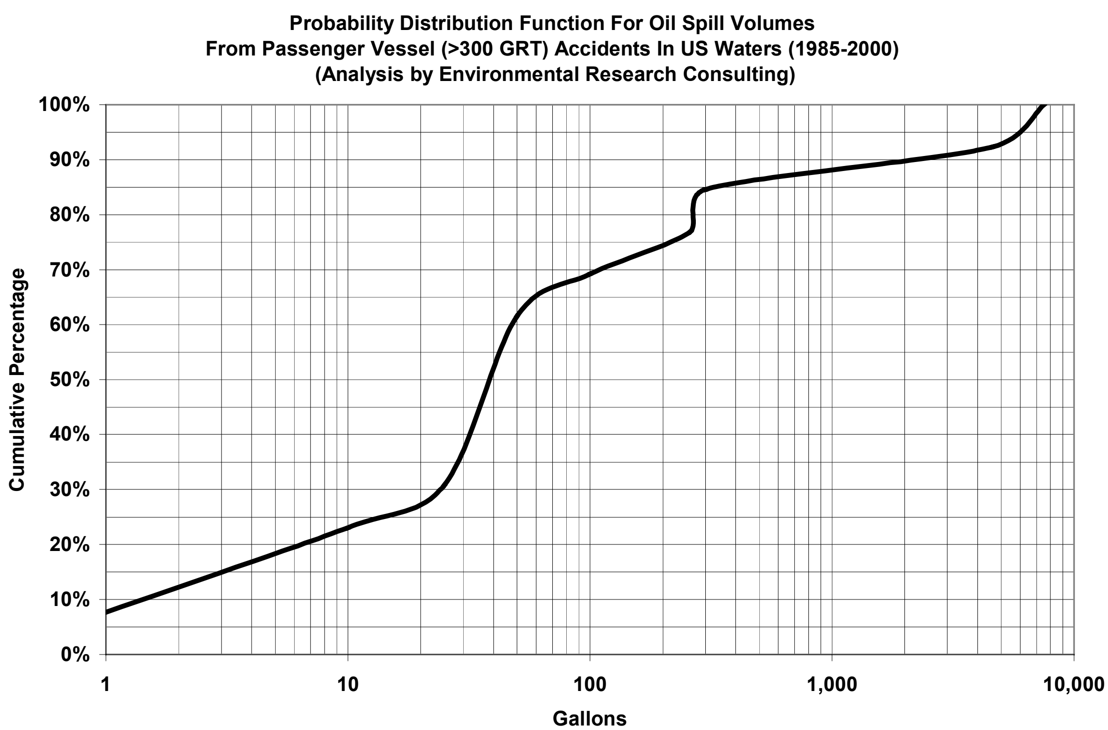


Figure 4.59

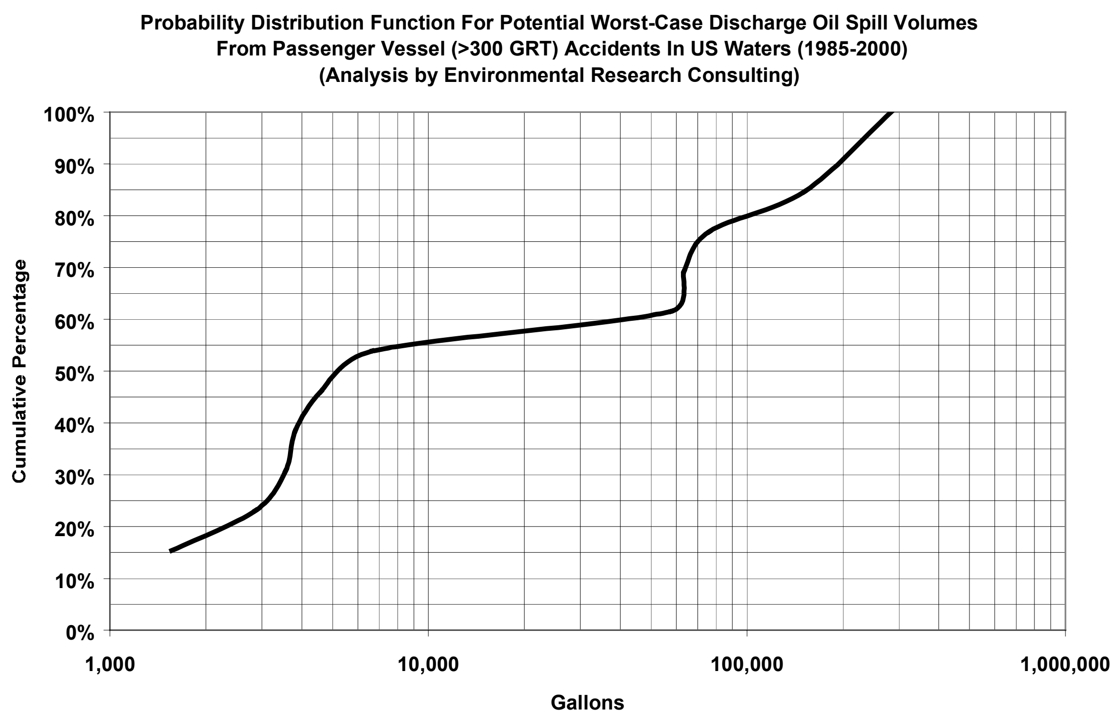
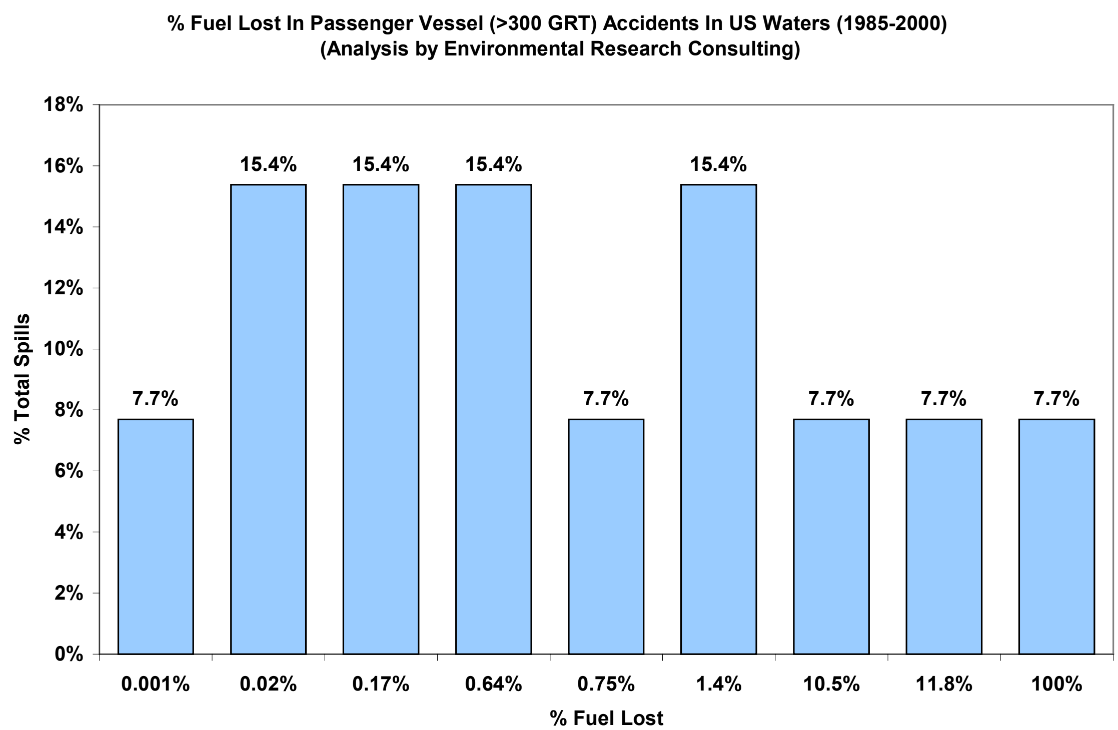


Figure 4.60



4.5.3 US Passenger Vessel (>300 GRT) Spills – Illegal Discharges/Pollution/Fueling

Figure 4.61

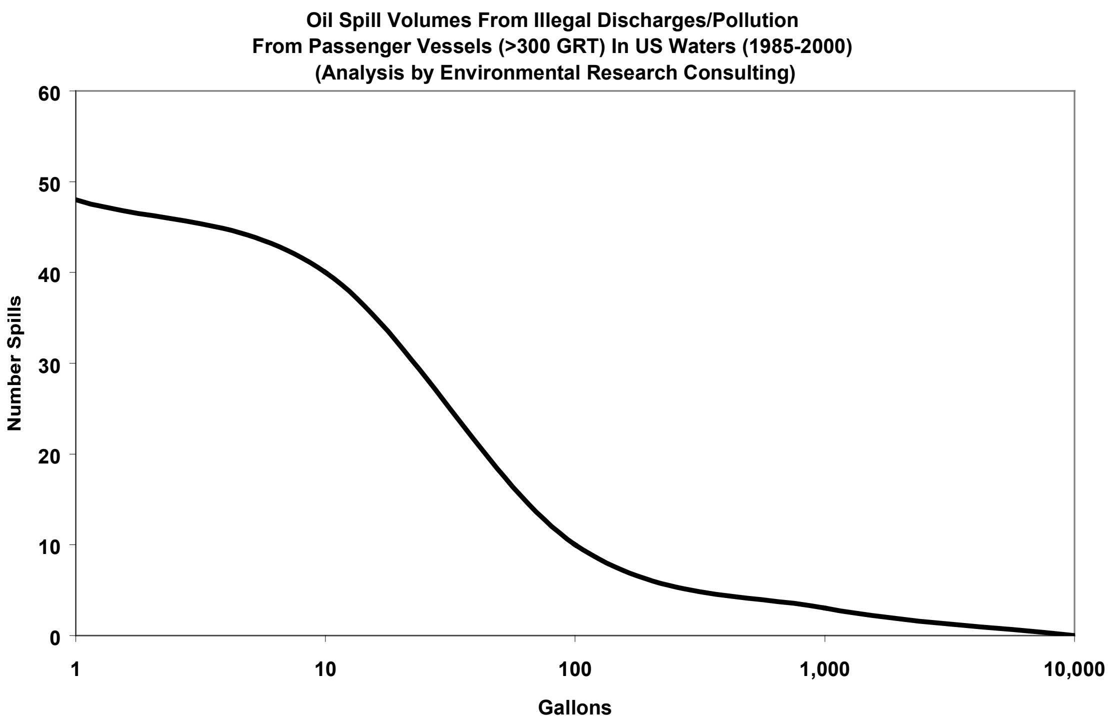


Figure 4.62

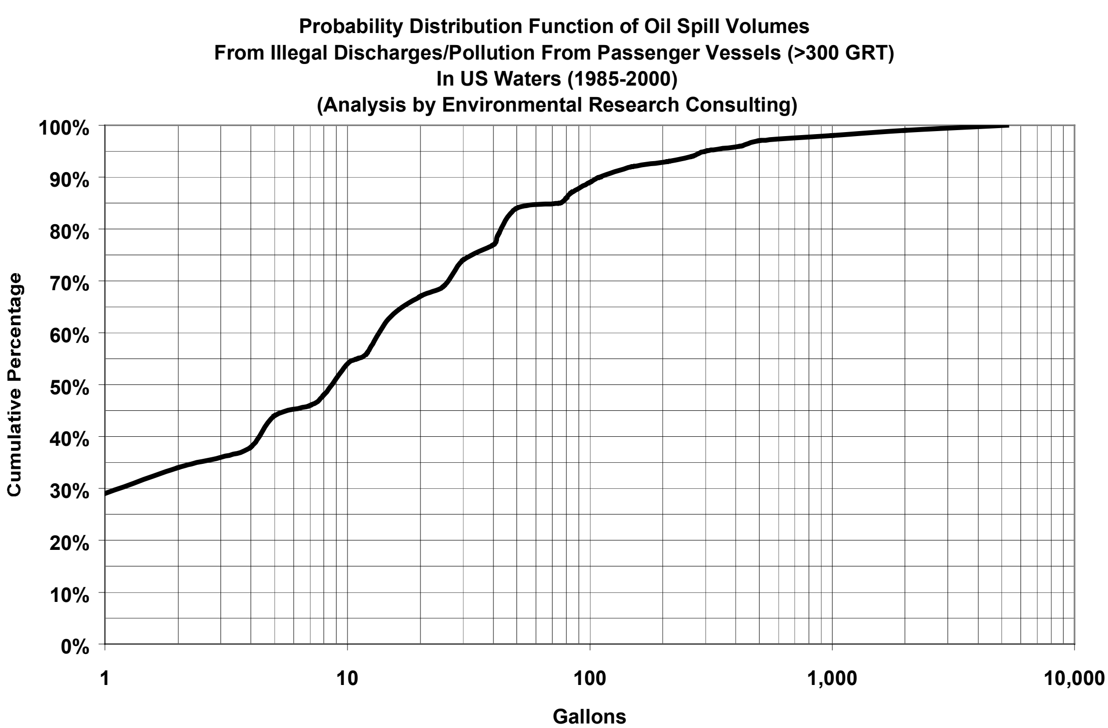


Figure 4.63

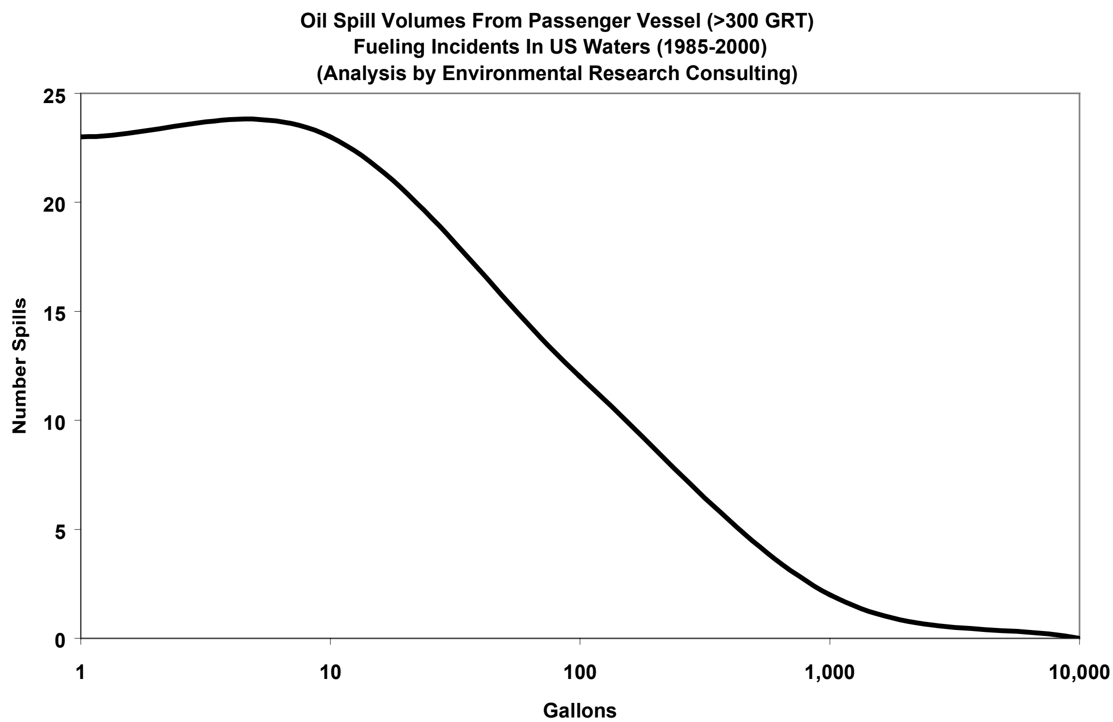


Figure 4.64

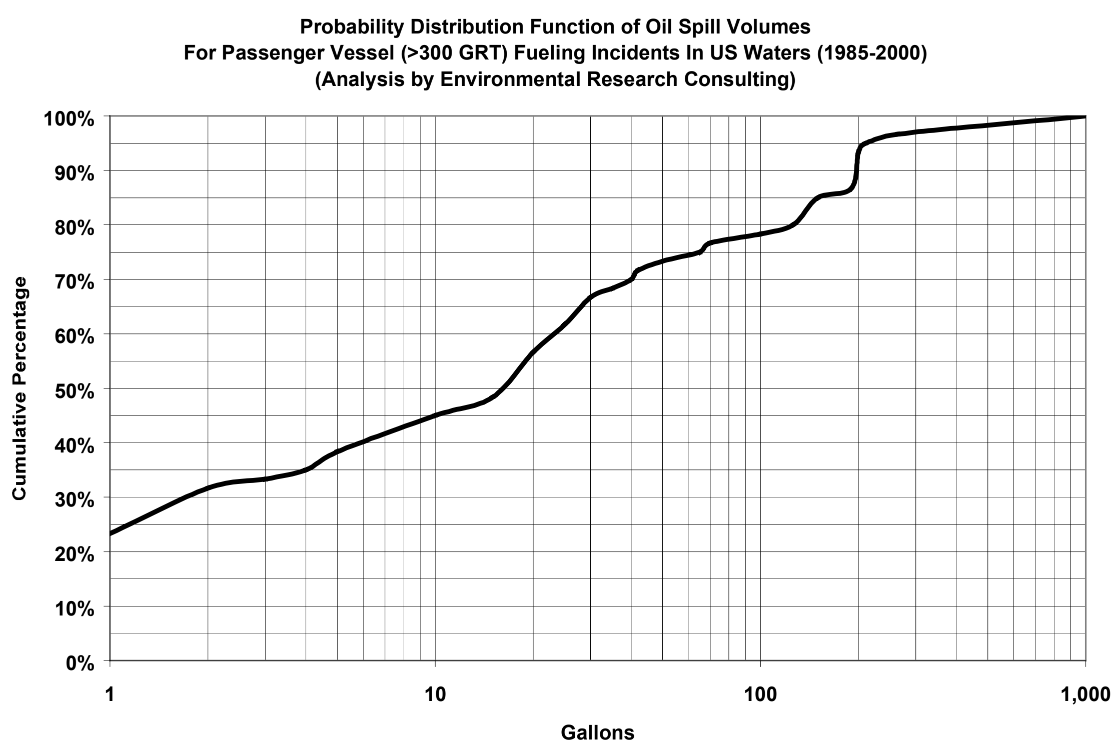


Table 4.5

Actual Vs. Potential Worst-Case Discharge Oil Spillage From Passenger Vessels in US Waters (1985-2000)							
Spill Type	PERCENTILE SPILLS (gallons) Actual Spill Volumes/Potential Worst-Case Discharge (shaded)[1]						
	10th	25th	50th	75th	90th	95th	Worst Case Discharge
Passenger Vessels ALL	1	1	12	45	200	400	7,500
	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Passenger Vessels Accidents	2	15	40	200	400	6,000	8,000
	1,000	3,000	5,000	70,000	200,000	225,000	300,000
Passenger Vessels Fueling[2]	1	2	15	60	200	300	1,000
	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Passenger Vessels Illegal Discharge[2]	1	1	9	30	100	300	5,300
	n/a	n/a	n/a	n/a	n/a	n/a	n/a

[1]Potential worst-case discharge (complete loss) based on assumption of 70%-full bunker tanks on freighters and other vessels.
[2]Worst-case discharge is not defined for general pollution incidents, lightering, de-ballasting, cargo loading/unloading, intentional discharges, and unintentional discharges (not related to allisions, groundings, collisions, structural failure, fire or sinking).
Percentile spills are defined as the percentage of spills that are *smaller* than this size, e.g., the 95th percentile spill is that spill size which is larger than 95% of spills (only 5% of spills are larger than this; 95% of spills are smaller than this).
Analysis by Environmental Research Consulting.

4.6 Vessel Spills -- Oil Types

The types of oil spilled by different types of vessels are shown in Table 4.6.

Table 4.6: Oil Spills From Vessels Into US Waters (1985-2000) By Oil Type

Source Type		Oil Type					
		Gasoline	**Light Distillates**	**Crude**	**Heavy Fuel**	**Waste**	**Other**
Tankers	**Spill Number**	111	435	557	818	230	104
	Total Spilled (gal)	426,192	577,482	18,511,756	1,667,943	15,572	16,657
	Avg. Spill Size	3,840	1,328	33,235	2,039	68	160
	% Total (#)	4.9%	19.3%	24.7%	36.3%	10.2%	4.6%
	% Total (Volume)	2.0%	2.7%	87.3%	7.9%	0.1%	0.1%
Barges	**Spill Number**	724	1,509	543	1,434	127	244
	Total Spilled (gal)	2,126,629	5,502,463	1,151,937	3,836,795	92,169	230,685
	Avg. Spill Size	2,937	3,646	2,121	2,676	726	945
	% Total (#)	15.8%	32.9%	11.9%	31.3%	2.8%	5.3%
	% Total (Volume)	16.4%	42.5%	8.9%	29.6%	0.1%	1.8%
Freighters (>300 GRT)	**Spill Number**	10	362	0	776	224	130
	Total Spilled (gal)	169	376,574	0	1,006,169	48,964	22,370
	Avg. Spill Size	17	1,040	0	1,297	219	172
	% Total (#)	0.7%	24.1%	0.0%	51.7%	14.9%	8.7%
	% Total (Volume)	0.01%	25.9%	0.0%	69.2%	3.4%	1.5%
Fishing Vessels (>300 GRT)	**Spill Number**	3	76	0	84	41	6
	Total Spilled (gal)	65	359,663	0	167,232	2,690	8
	Avg. Spill Size	22	4,732	0	1,991	66	1
	% Total (#)	1.4%	36.2%	0.0%	40.0%	19.5%	2.9%
	% Total (Volume)	0.01%	67.9%	0.0%	31.6%	0.5%	<0.01%
Passenger Vessels (>300 GRT)	**Spill Number**	0	40	0	77	37	18
	Total Spilled (gal)	0	7,027	0	20,809	1,193	632
	Avg. Spill Size	0	176	0	270	32	35
	% Total (#)	0.0%	23.3%	0.0%	44.8%	21.5%	10.5%
	% Total (Volume)	0.0%	23.7%	0.0%	70.2%	4.0%	2.1%

Analysis by Environmental Research Consulting

5.0 Washington State Historical Vessel Spill Analysis

The results of the analysis of vessel spills that occurred in Washington State during 1985-2000 are shown in this section.

5.1 Washington State Historical Tanker Spills

An analysis of historical tanker spills (of all causes) for Washington State is shown in Figures 5.1-5.3.

Figure 5.1

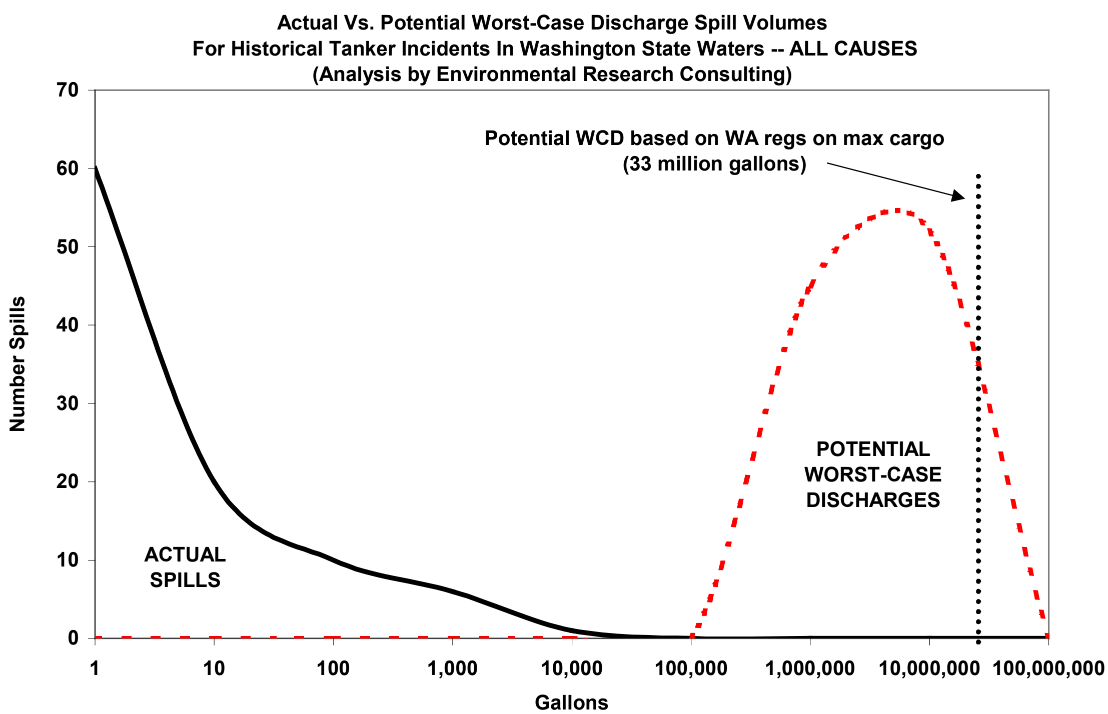


Figure 5.2

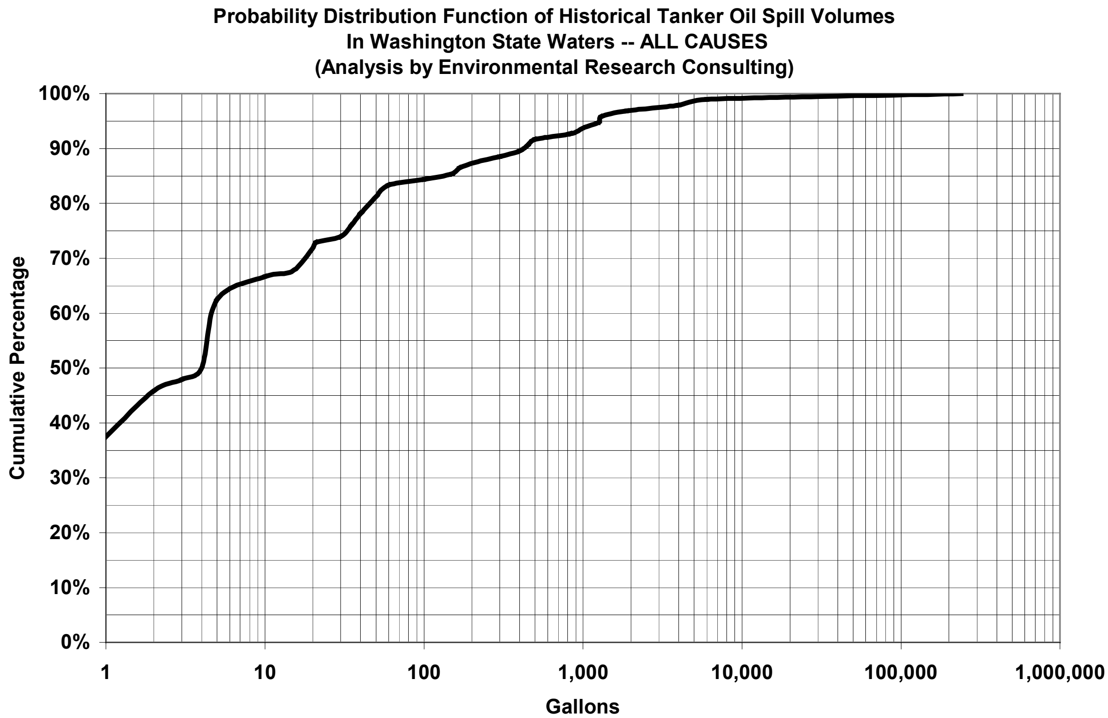
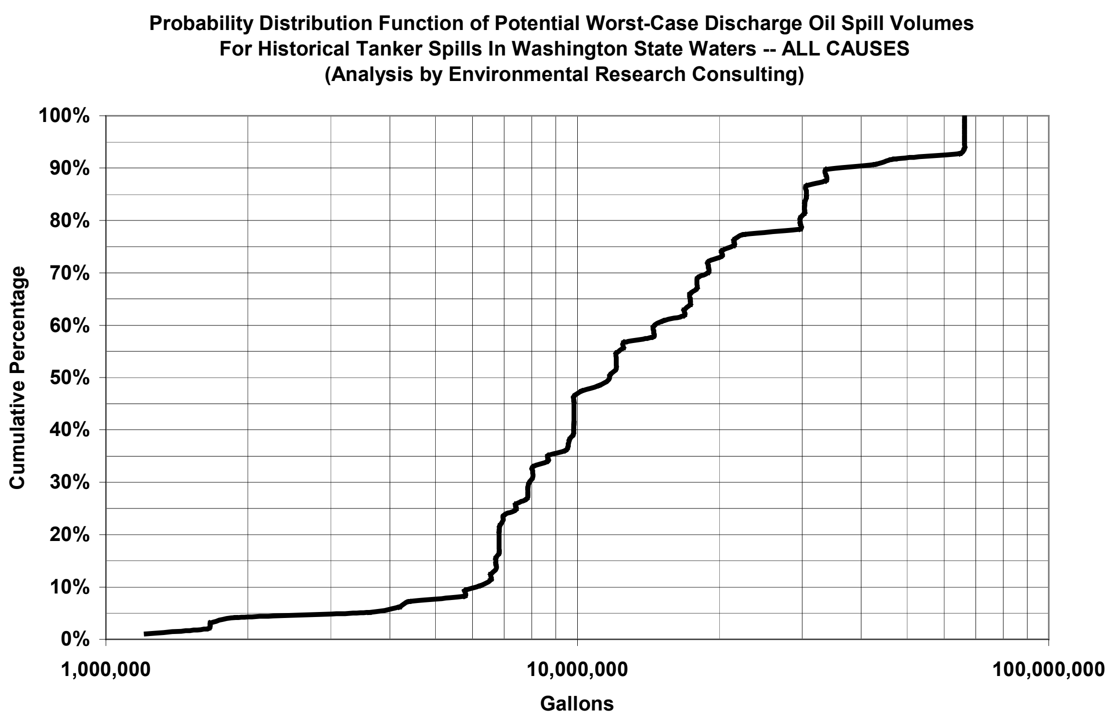


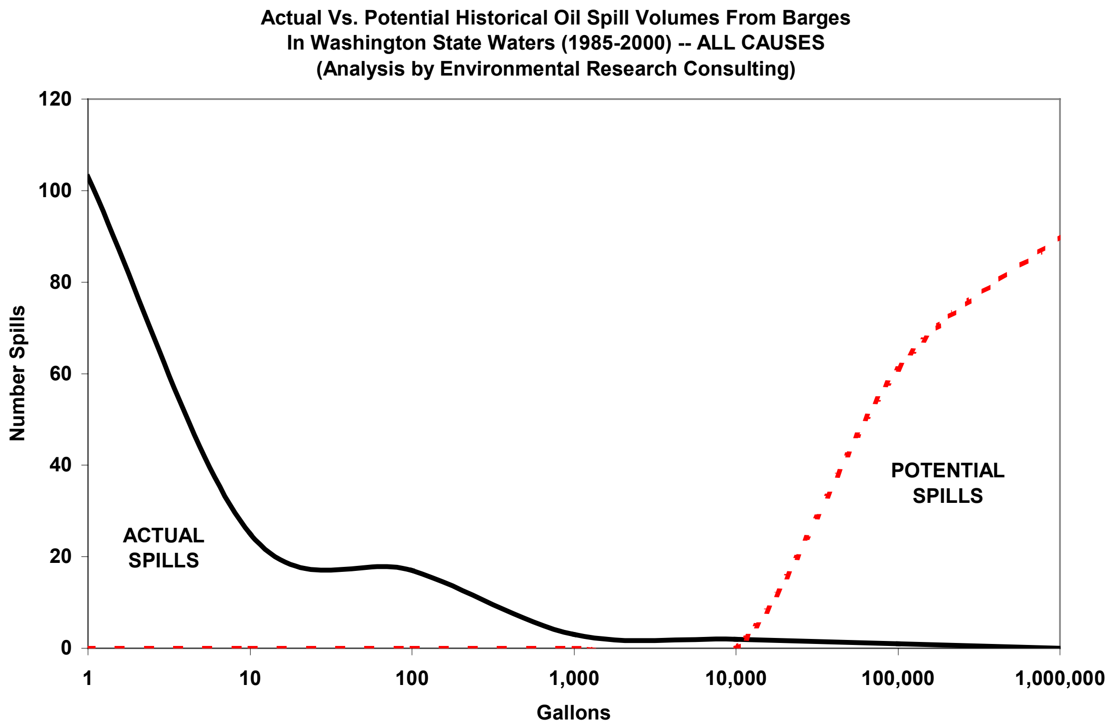
Figure 5.3



5.1 Washington State Historical Barge Spills

The analysis results for Washington State barge spills are shown in Figures 5.4 – 5.6.

Figures 5.4 and 5.5



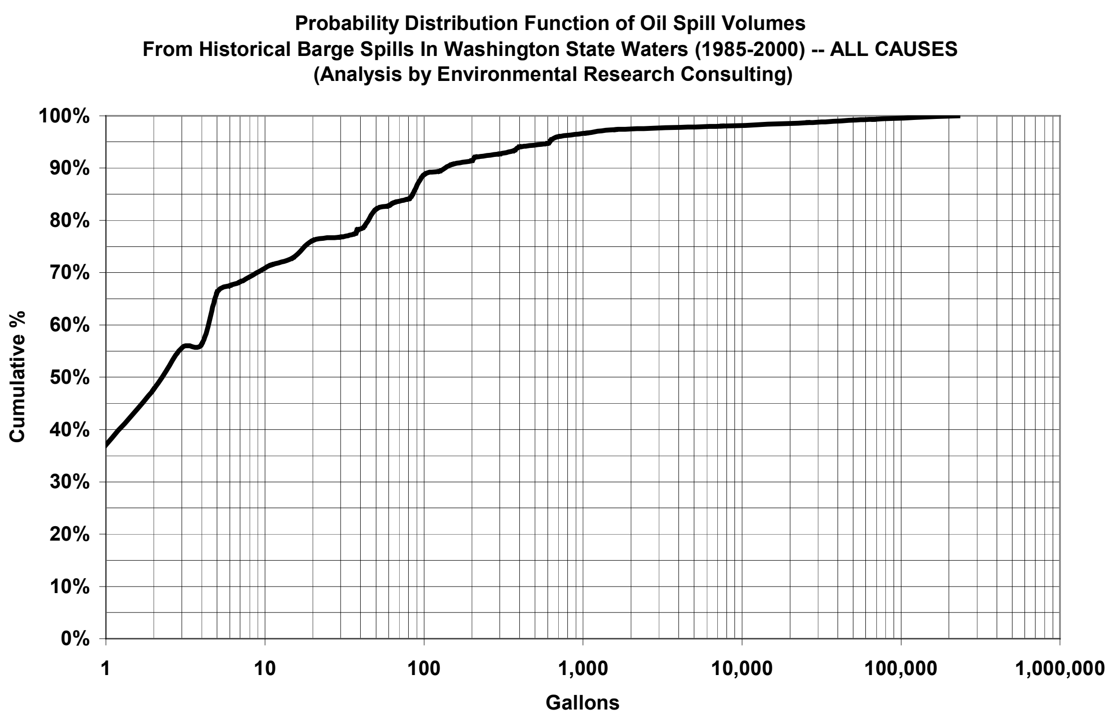
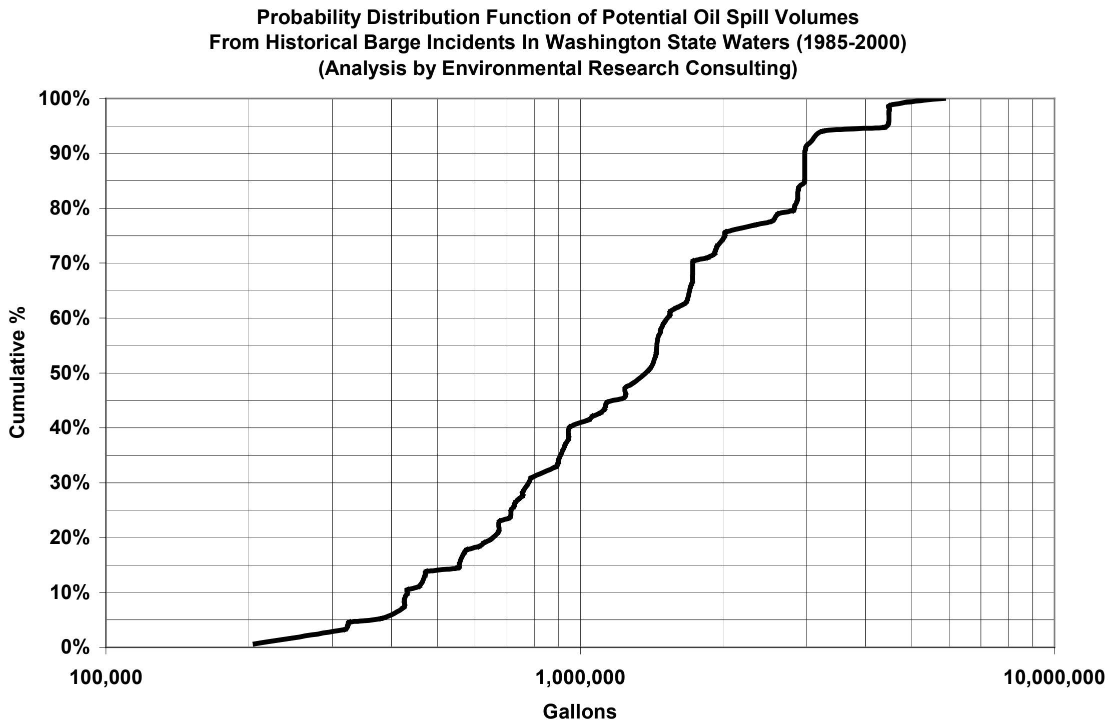


Figure 5.6



5.3 Washington State Historical Freighter (>300 GRT) Spills

Analyses of historical spills from >300 GRT freight vessels are shown in Figures 5.7-5.9.

Figure 5.7

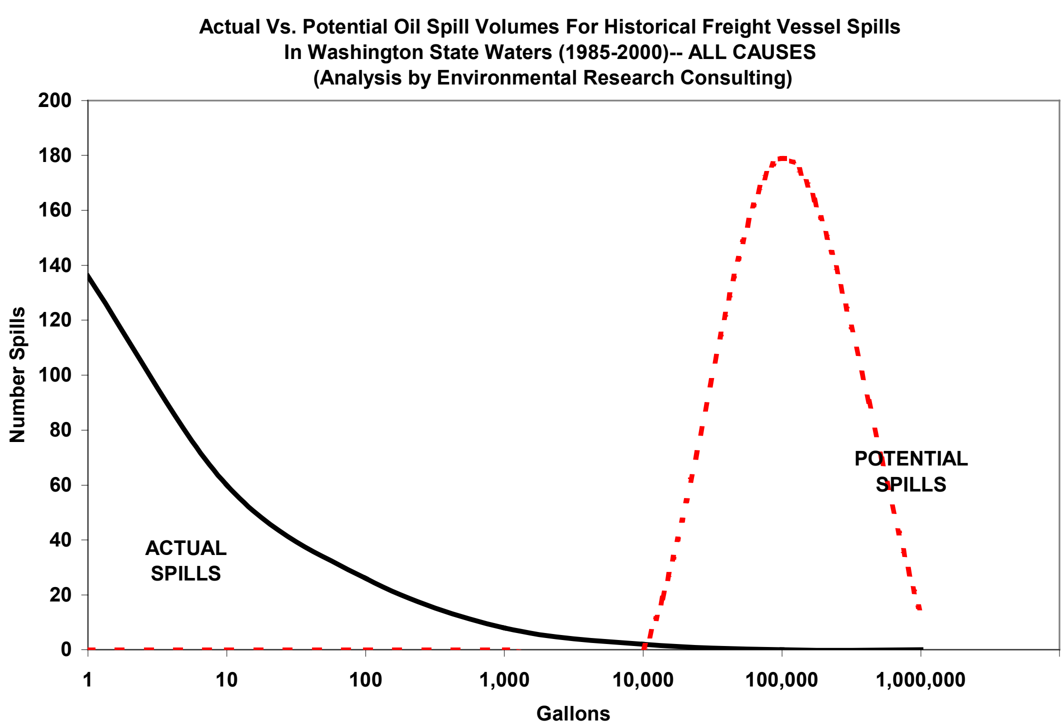


Figure 5.8

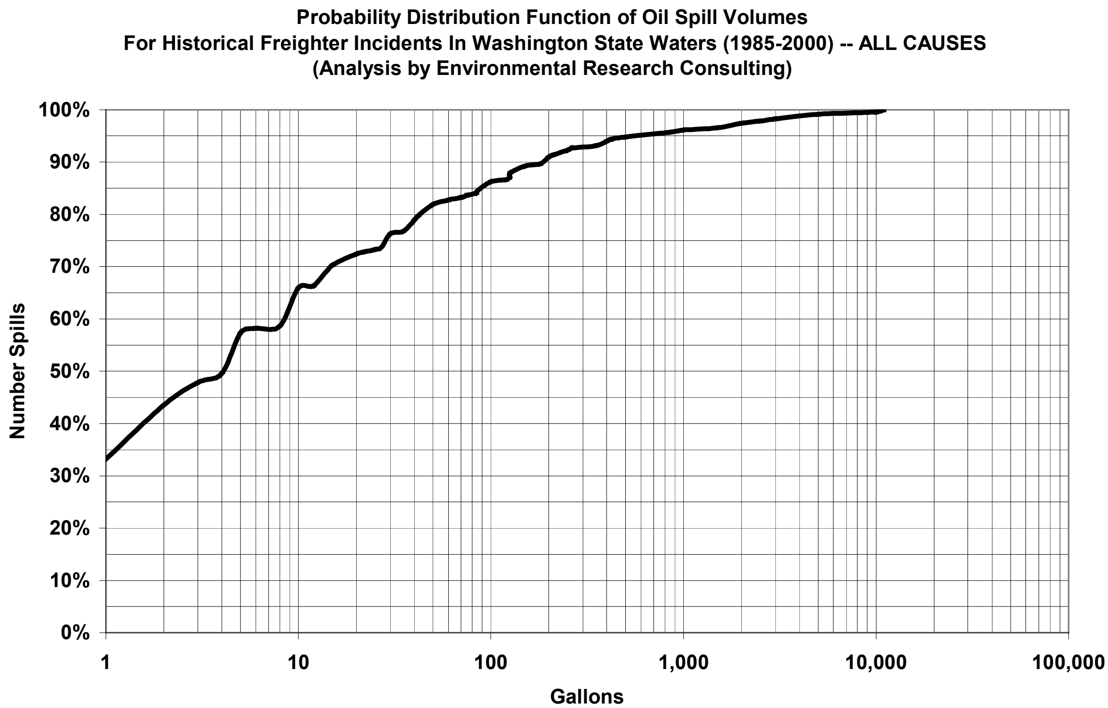
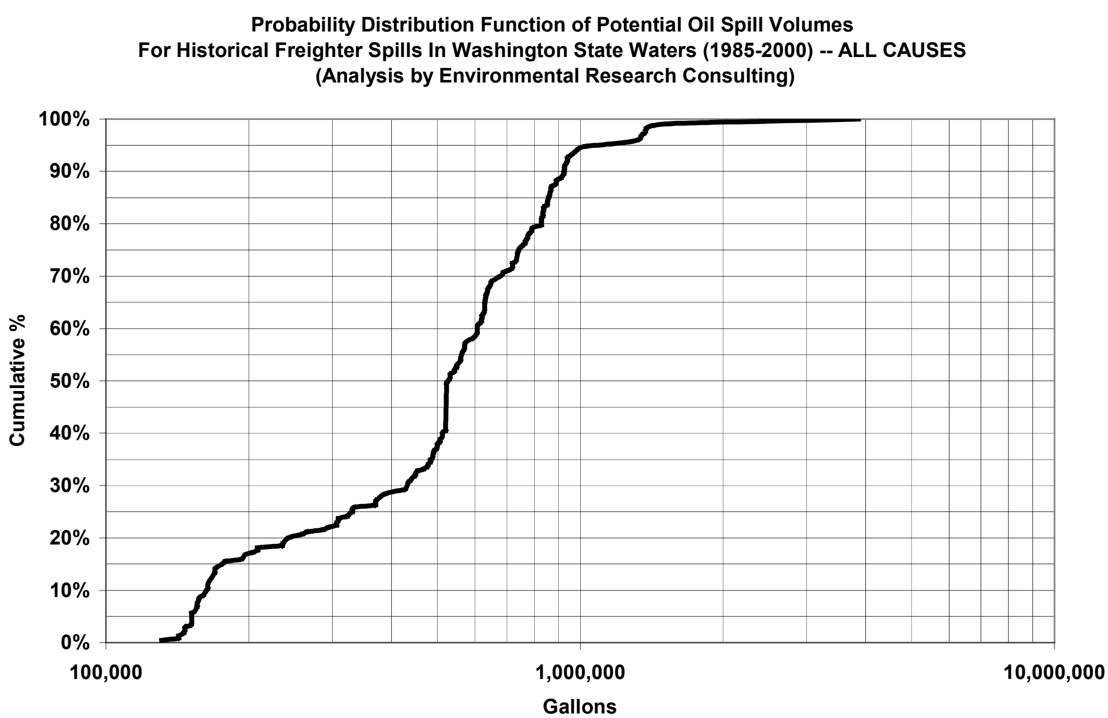


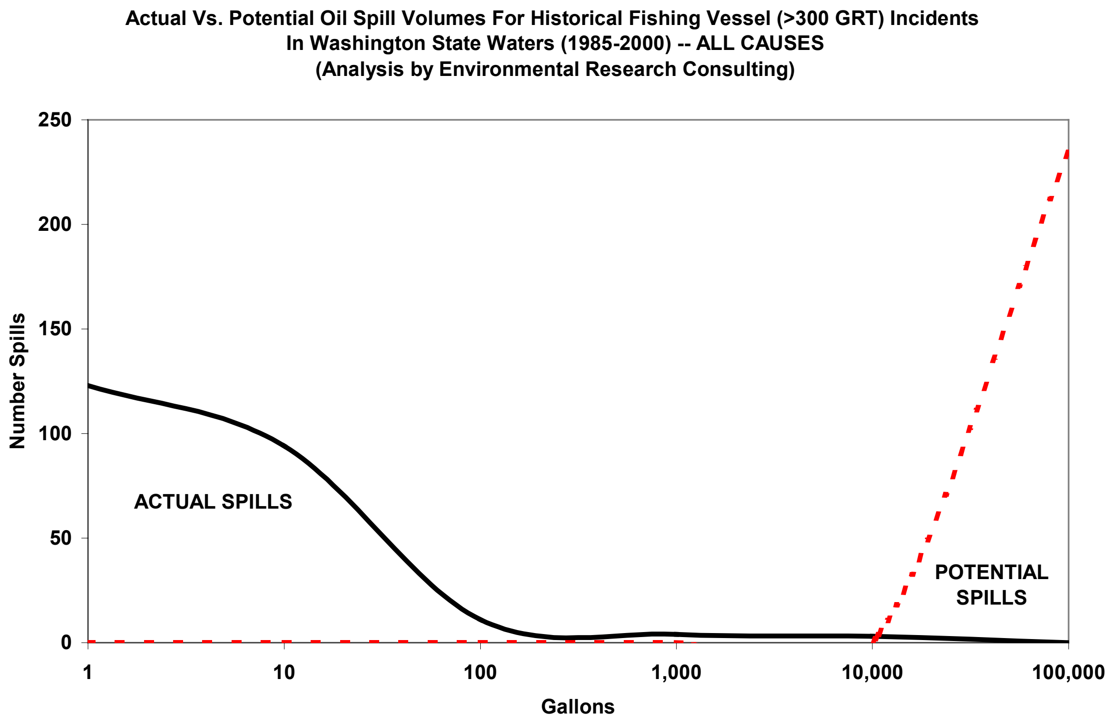
Figure 5.9



5.4 Historical Fishing Vessel (>300 GRT) In Washington State

Historical Washington State fishing vessel spill analyses are shown in Figures 5.10-5.12.

Figures 5.10 – 5.11



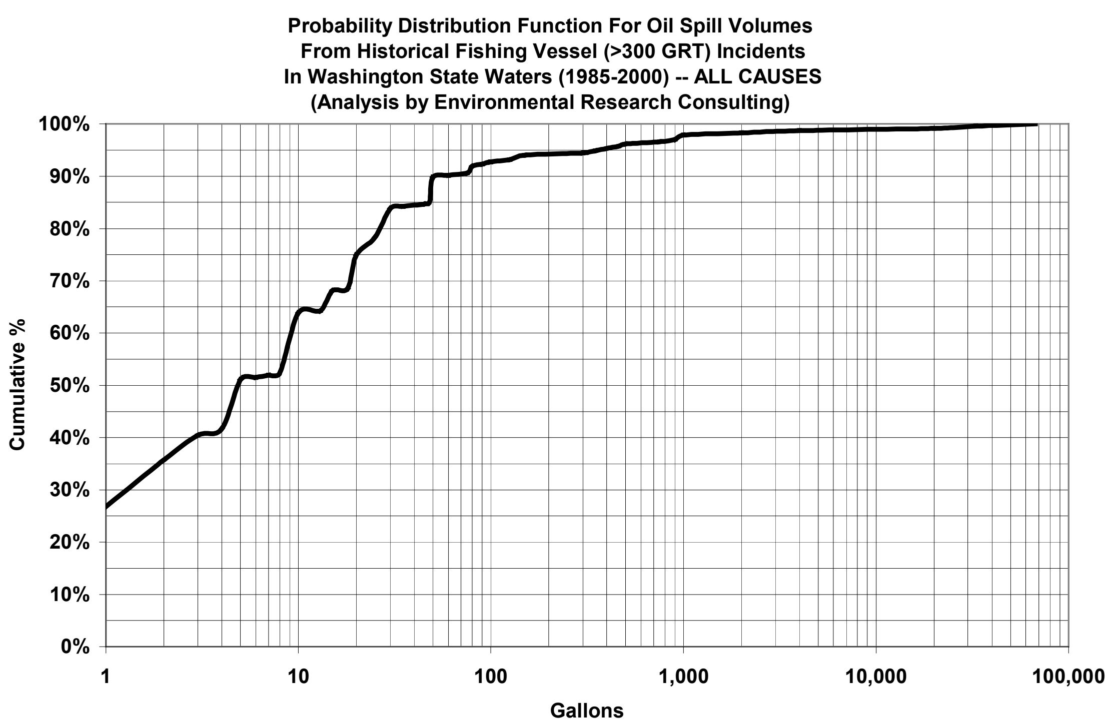
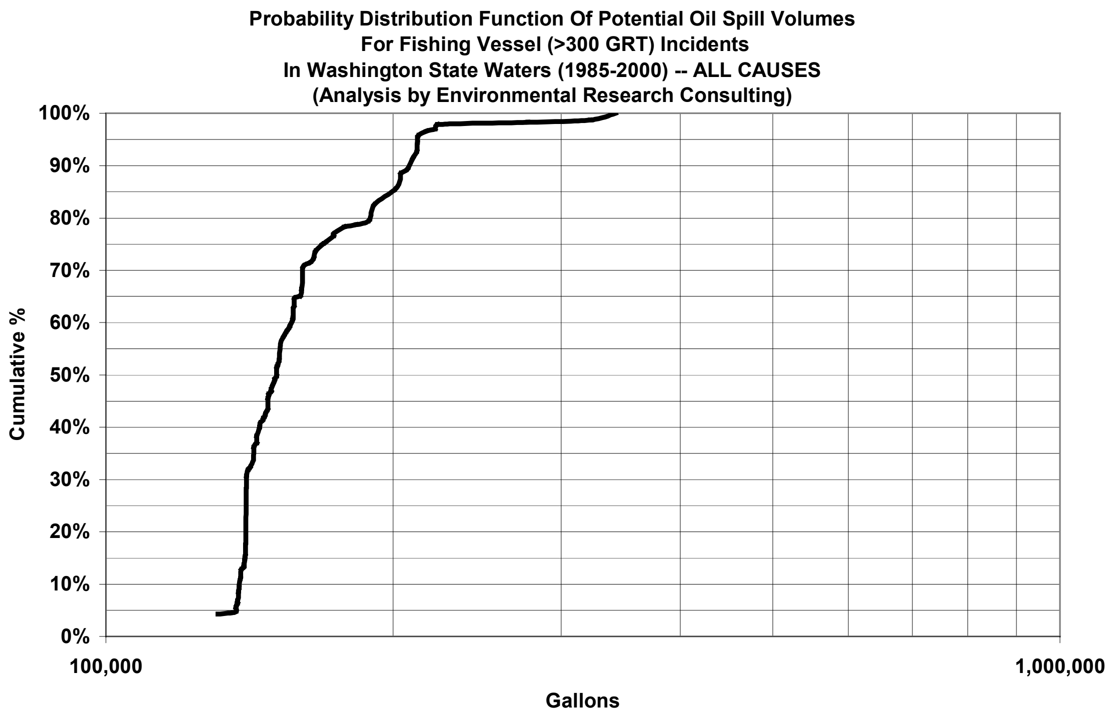


Figure 5.12



5.5 Historical Passenger Vessel (>300 GRT) In Washington State

Analyses of historical passenger vessel spills in Washington State are shown in Figures 5.13-5.15.

Figure 5.13

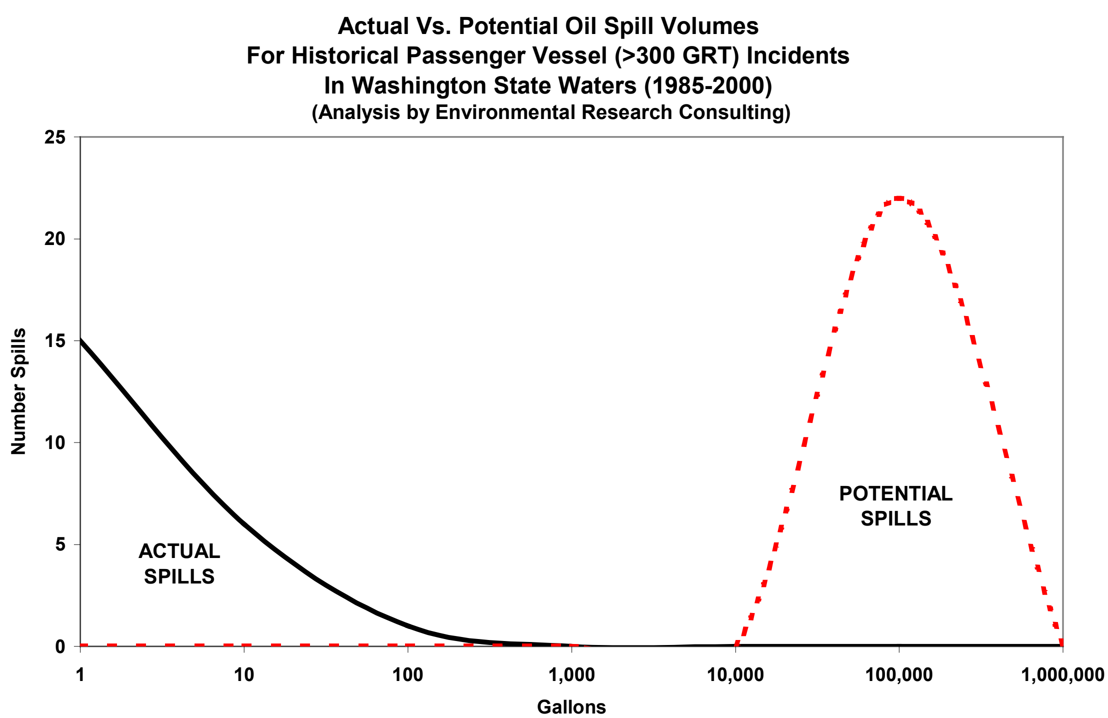


Figure 5.14

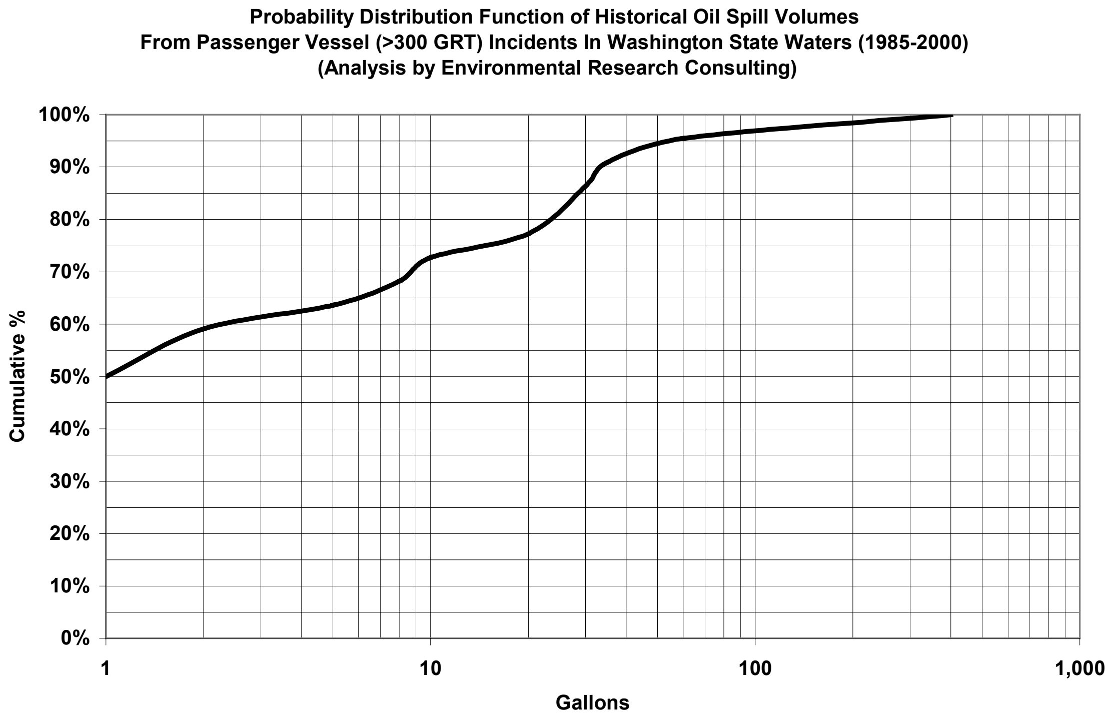
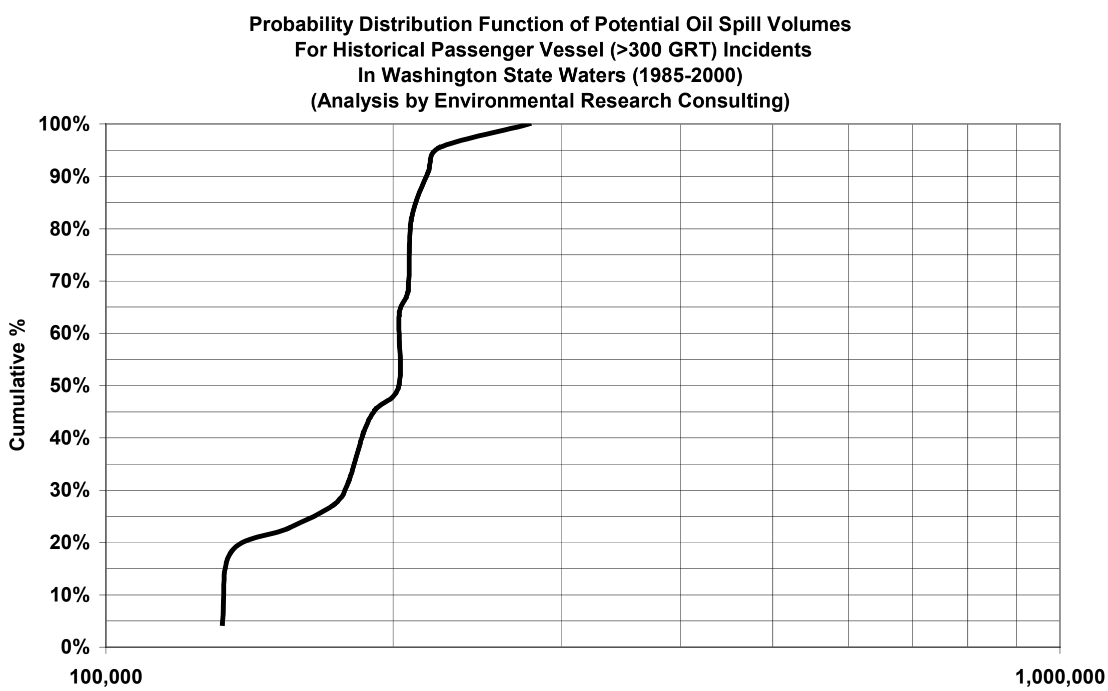


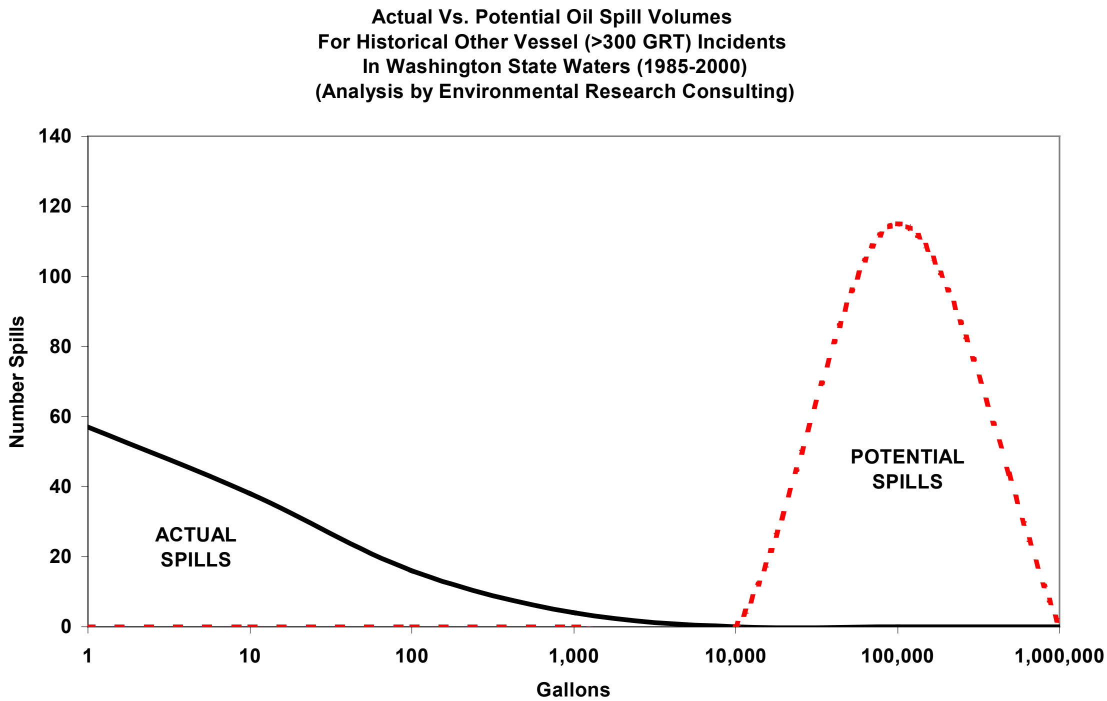
Figure 5.15



5.6 Historical Other Vessel (>300 GRT) Spills In Washington State

Historical vessel spills (>300 GRT) not covered under other categories are analyzed in Figures 5.16-5.18.

Figure 5.16 –5.17



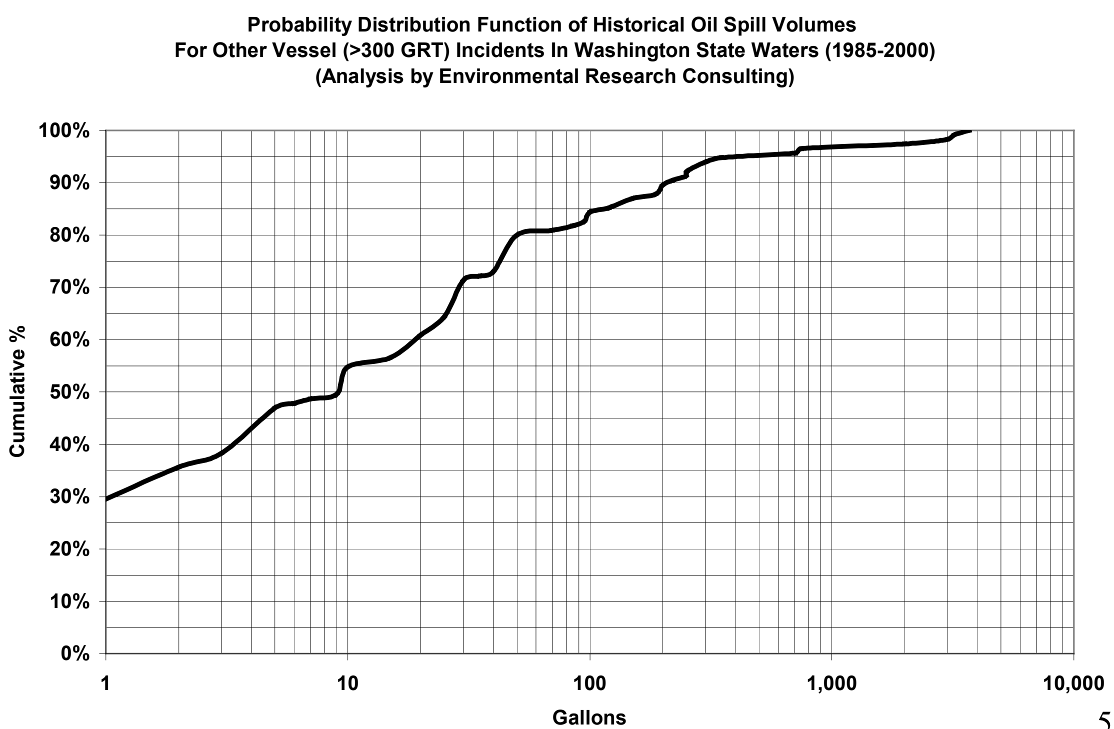
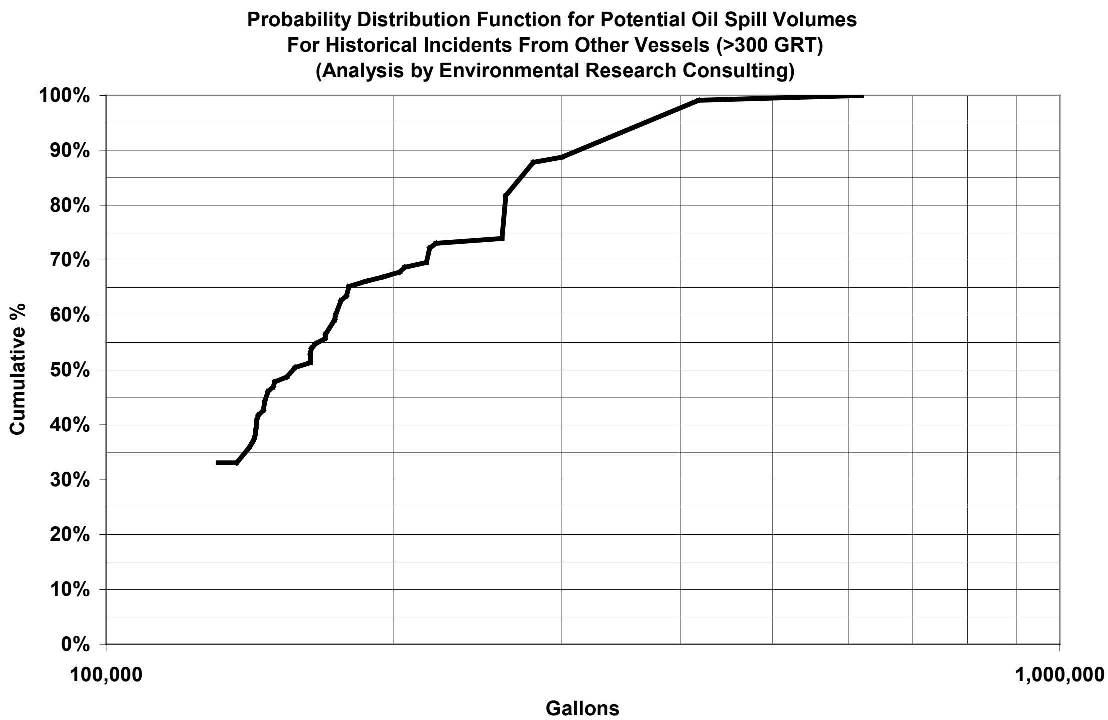


Figure 5.19



The percentile oil spill volumes for historical Washington State vessel spills and the corresponding potential volumes of theoretical worst-case discharges (based on oil cargo or fuel on board) are shown in Table 5.1.

Table 5.1 Actual Vs. Potential Worst-Case Discharge Oil Spills From Vessels (>300 GRT) In Washington State Waters (1985-2000)

Spill Type	PERCENTILE SPILLS (gallons) Actual Spill Volumes/Potential Worst-Case Discharge (shaded)[1]						
	10th	**25th**	**50th**	**75th**	**90th**	**95th**	**Worst Case Discharge**
Tankers	1	1	4	20	400	1,500	250,000
	6 mil.	7.5 mil	11 mil	21 mil.	40 mil.	65 mil.	108 mil.
Barges	1	2	10	100	50,000	100,000	250,000
	600,000	800,000	1.3 mil.	2.5 mil.	2.6 mil.	2.7 mil.	2.8 mil.
Freighters	1	1	4	30	200	800	11,000
	150,000	305,000	550,000	750,000	900,000	1 mil.	4 mil.
Fishing	1	1	5	20	60	300	70,000
	120,000	140,000	150,000	180,000	200,000	220,000	350,000
Passenger	1	1	1	9	32	60	400
	120,000	150,000	200,000	210,000	230,000	240,000	270,000
Other	1	1	9	40	200	800	4,000
	120,000	140,000	150,000	250,000	300,000	350,000	610,000

[1]Potential worst-case discharge (complete loss) based on assumption of 70%-full bunker tanks on freighters and other vessels.

Percentile spills are defined as the percentage of spills that are *smaller* than this size, e.g., the 95th percentile spill is that spill size which is larger than 95% of spills (only 5% of spills are larger than this; 95% of spills are smaller than this).

Analysis by Environmental Research Consulting.

6.0 Application of US Analysis To Washington State Vessel Traffic

Analyses of expected accidental vessel spill volumes for vessels transiting Washington State waters, based on an application of US tanker losses and probabilities onto Washington State vessel traffic data (as shown in Table 6.1) are described in this section. Only accidental causes (collisions, allisions, groundings, structural failures, and fire) are covered.

Table 6.1 Vessel and Oil Movements Through Puget Sound (2000)

Vessel Type	Vessel Size	Oil Movement Per Transit (gallons)			Transits Per Year
		Crude Oil	Refined Product	Bunker Fuel	
Crude tankers (laden)	<75,000 DWT	16,844,000	--	352,200	79
	75,000-110,000 DWT	22,000,000	--	396,300	81
	>110,000 DWT	32,718,000	--	660,450	138
Crude tankers (ballast)	avg. 67,000 DWT	--	--	352,200	6
Product tankers (laden)	avg. 22,000 DWT	--	4,376,000	330,200	12
	avg. 55,000 DWT	--	10,941,000	176,100	23
Product tankers (ballast)	avg. 22,000 DWT	--	--	330,200	20
	avg. 55,000 DWT	--	--	176,100	179
Product barges (laden)	avg. 6,000 DWT	--	1,910,000	47,000	5
	avg. 12,000 DWT	--	3,819,000	47,000	18
Bulk carriers	<50,000 DWT	--	--	143,100	1,913
	50,000-100,000 DWT	--	--	242,200	501
	>100,000 DWT	--	--	440,300	122
Bulk liquid carriers		--	--	176,100	186
Containerships	<2,500 TEU	--	--	264,200	435
	2,500-4,000 TEU	--	--	484,300	510
	>4,000 TEU	--	--	825,600	394
Vehicle carriers		--	--	297,200	316
Factory fishing vessels	300-3,000 GRT	--	--	54,000	59
	>3,000 GRT	--	--	165,100	112
Fishing boats	>300 GRT	--	--	26,400	167
Passenger vessels	300-3000 GRT	--	--	52,800	16
	>3,000 GRT	--	--	140,900	11
Adapted from Herbert Engineering, et al. 1999					

6.1 Theoretical Washington State Tanker Spills – Accidents

Analyses of expected accidental tanker spill volumes from vessels transiting Washington State waters, based on an application of US tanker losses and probabilities onto Washington State vessel traffic data are shown in Figures 6.1 – 6.2.

Figures 6.1

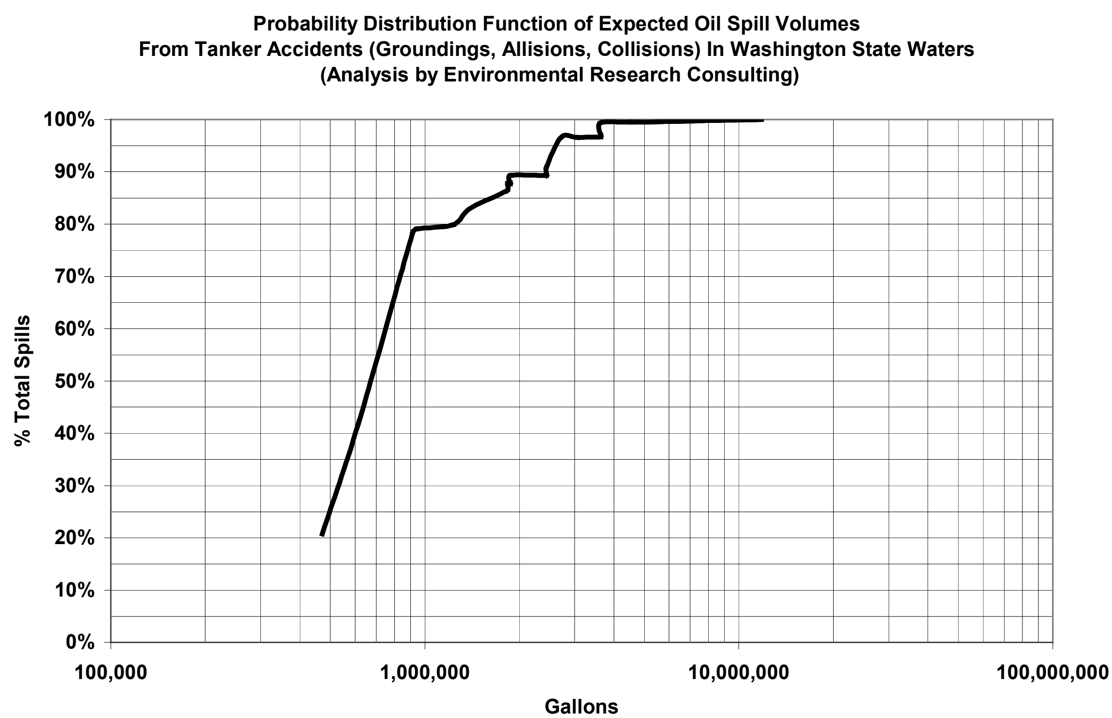
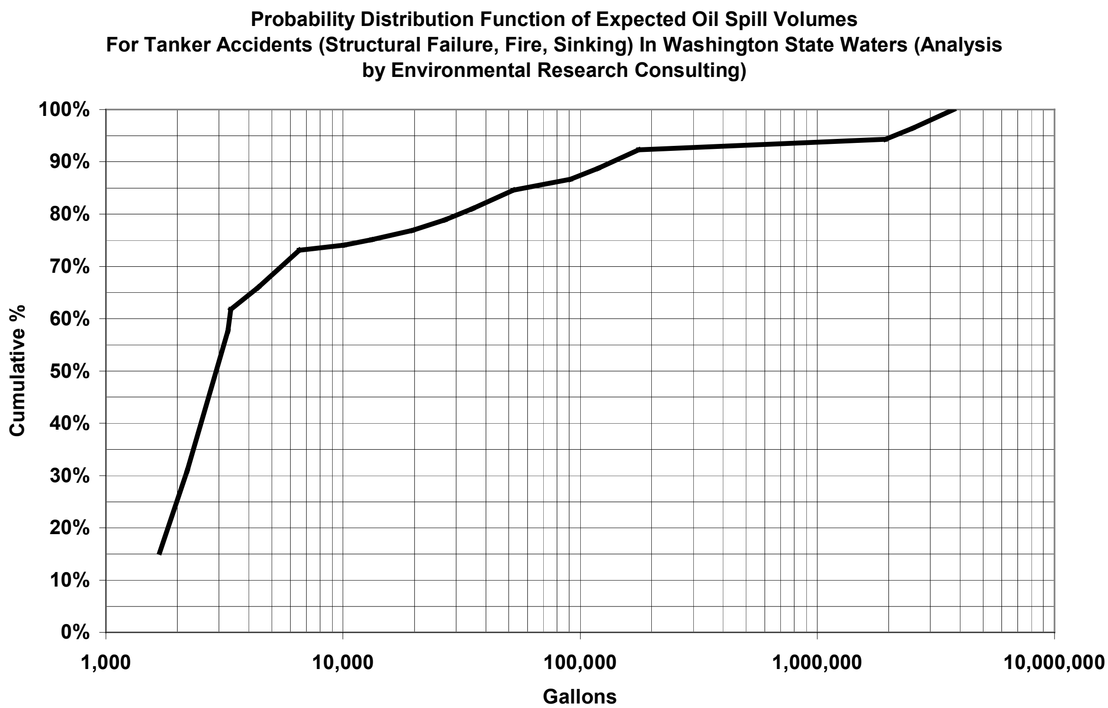


Figure 6.2



6.2 Theoretical Washington State Barge Spills – Accidents

The same analyses for barge spills are shown in Figure 6.3-6.4.
Figure 6.3

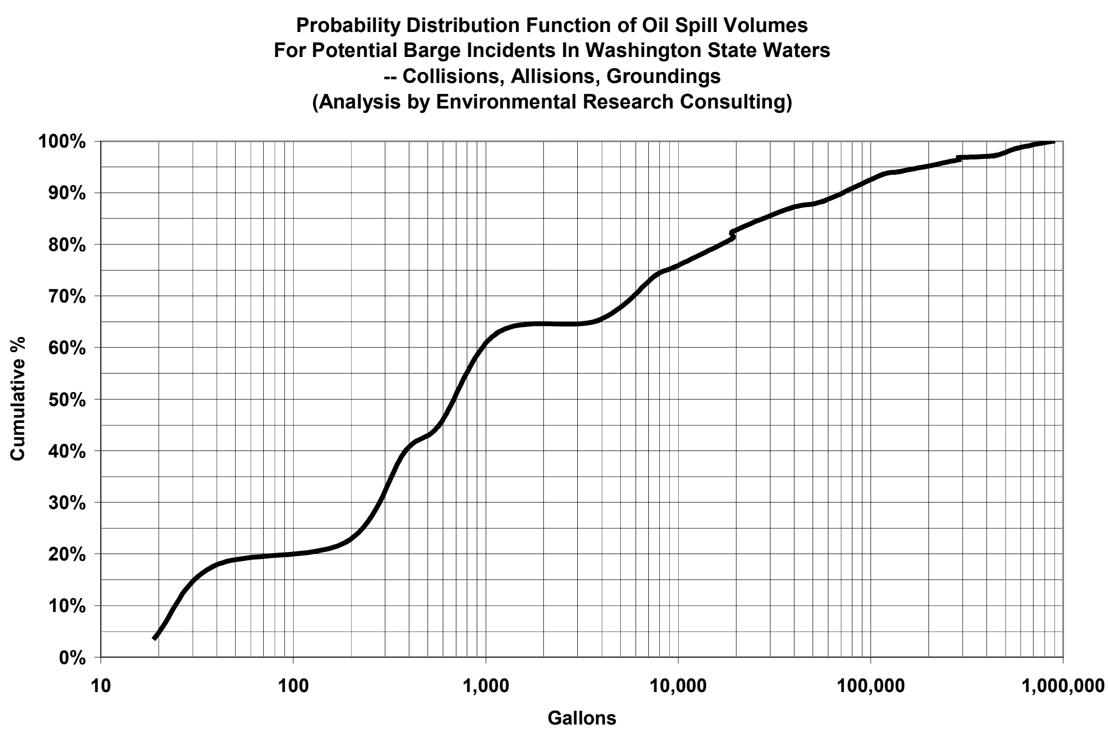
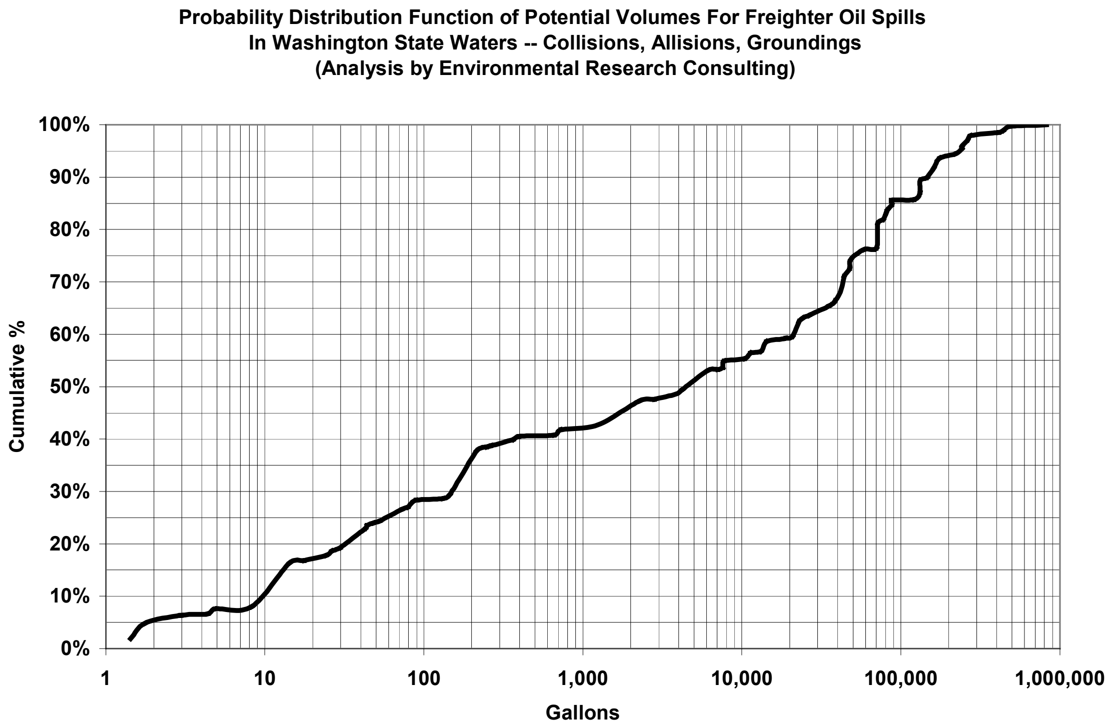


Figure 6.4



6.2 Theoretical Washington State Freighter Spills – Accidents

The analyses for freighter spills are shown in Figures 6.5 – 6.6
Figure 6.5

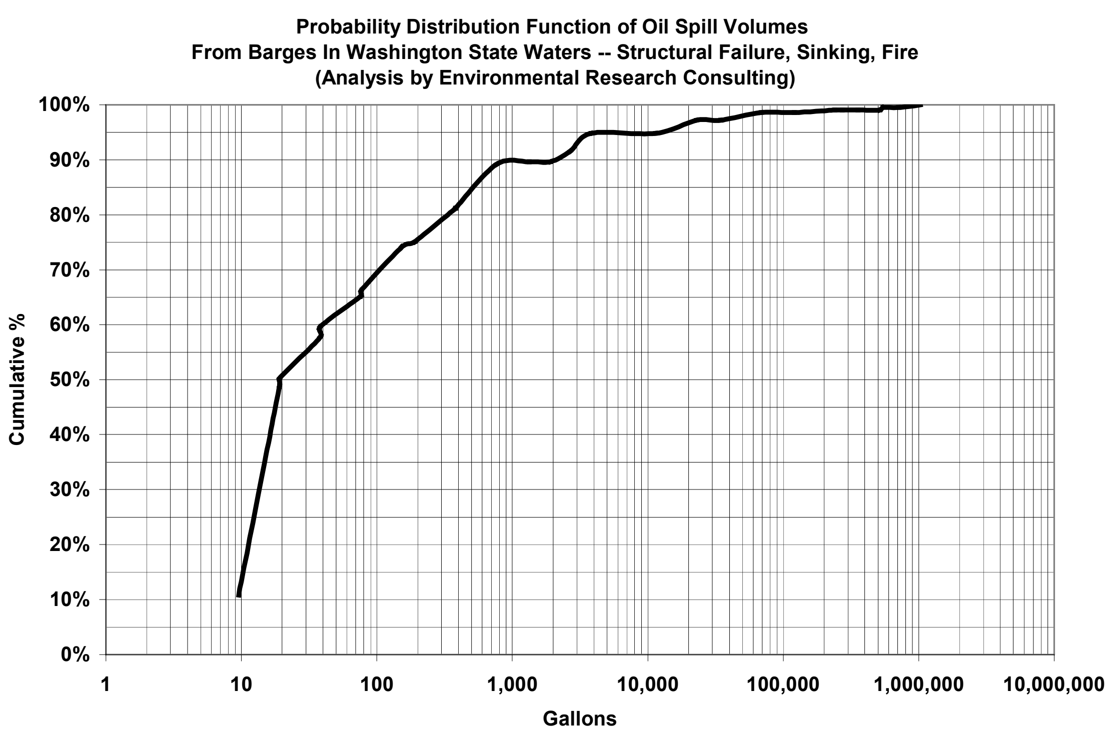
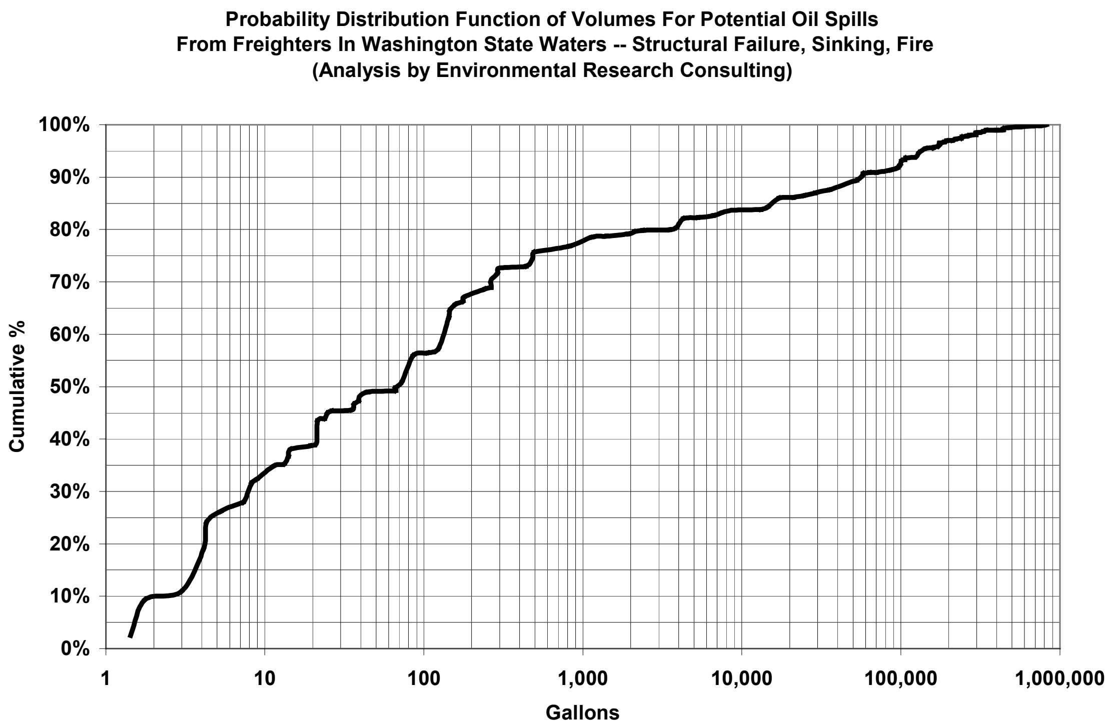


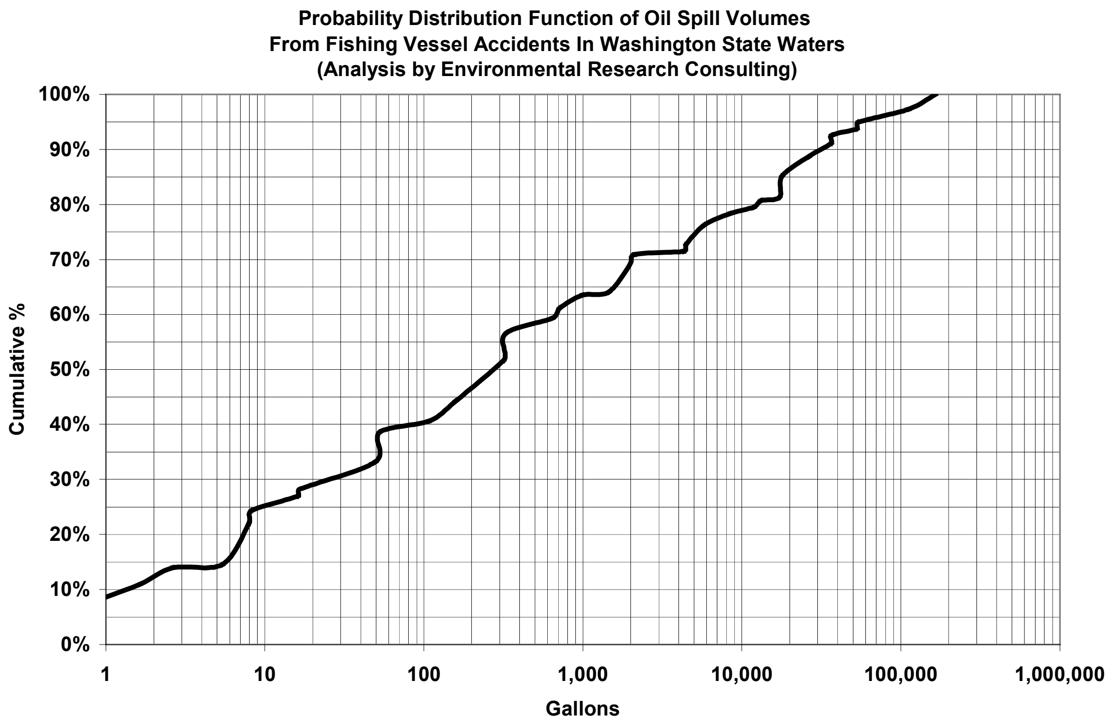
Figure 6.6


Probability Distribution Function of Volumes For Potential Oil Spills
From Freighters In Washington State Waters -- Structural Failure, Sinking, Fire
(Analysis by Environmental Research Consulting)
Cumulative %
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
1
10
100
1,000
10,000
100,000
1,000,000
Gallons

6.4 Theoretical Washington State Fishing Vessel Spills – Accidents

Analyses for fishing vessel spills are shown in Figure 6.7.

Figure 6.7



6.5 Theoretical Washington State Passenger Vessel Spills – Accidents

Analyses for passenger vessel spills are shown in Figure 6.8.

Figure 6.8

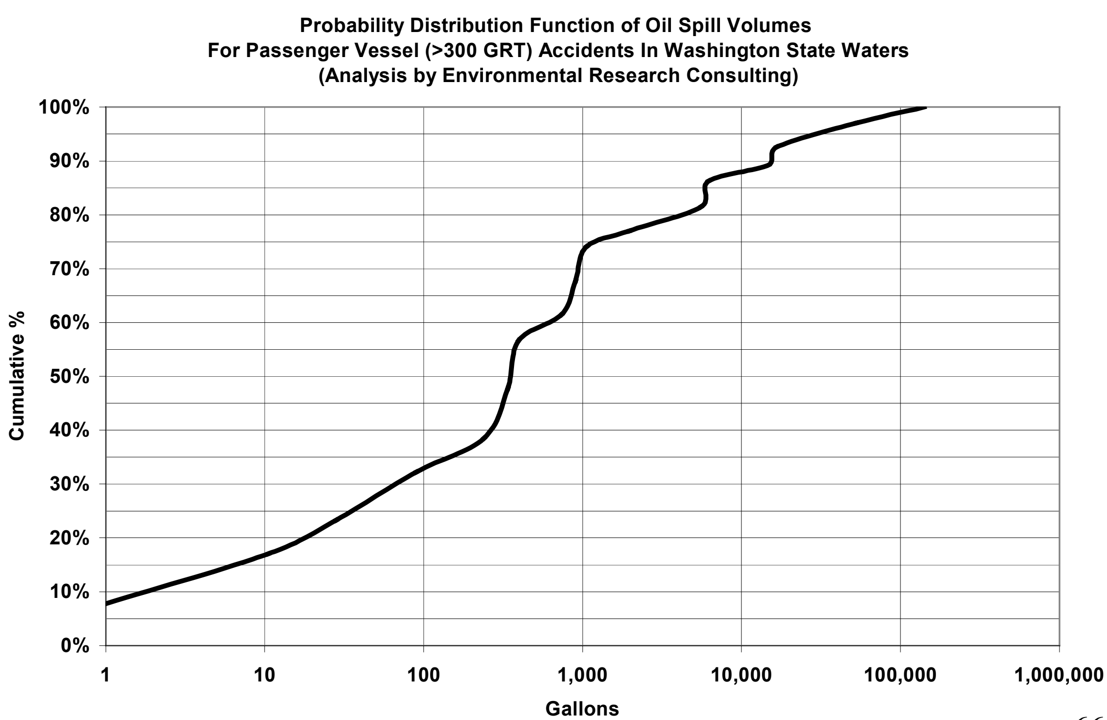


Table 6.2 shows the percentile spills for potential vessel spills in Washington State waters.

Table 7.2 Theoretical Potential Oil Spill Scenarios From Tankers In Washington State Waters Based on Modeling of US Spill Data

Spill Cause(s)	Percentile Spills (gallons)							
	10th	**25th**	**50th**	**75th**	**90th**	**95th**	**Most Probable WCD**	**Theoretical WCD**
Tanker Collision/Allision Grounding	400,000	500,000	700,000	900,000	2,000,000	2,400,000	12,000,000	32,718,000
Tanker Structural Failure Fire/Sinking	1,500	2,000	3,000	15,000	150,000	2,000,000	3,800,000	32,718,000
Barge Collision/Allision Grounding	40	200	800	10,000	80,000	287,000	880,000	3,800,000
Barge Structural Failure Fire/Sinking	10	15	20	200	1,000	23,000	1,031,000	3,800,000
Freighter Collision/Allision Grounding	10	60	310	5,800	36,000	54,000	825,600	825,600
Freighter Structural Failure Fire/Sinking	2	5	70	500	58,000	210,000	825,600	825,600
Fishing Vessel Accidents	1	10	310	5,800	36,000	54,000	165,100	165,100
Passenger Vessel Accidents	1	90	400	1,000	15,000	53,000	141,000	141,000

Analysis by Environmental Research Consulting

.0 US Coastal Facility Oil Spills Analysis

The results of analyses of coastal facility spills that occurred in US waters are shown in this section.

7.1 US Coastal Pipeline Spills – All Causes

Analyses of coastal pipeline spills are shown in Figures 7.1 –7.2.

Figure 7.1

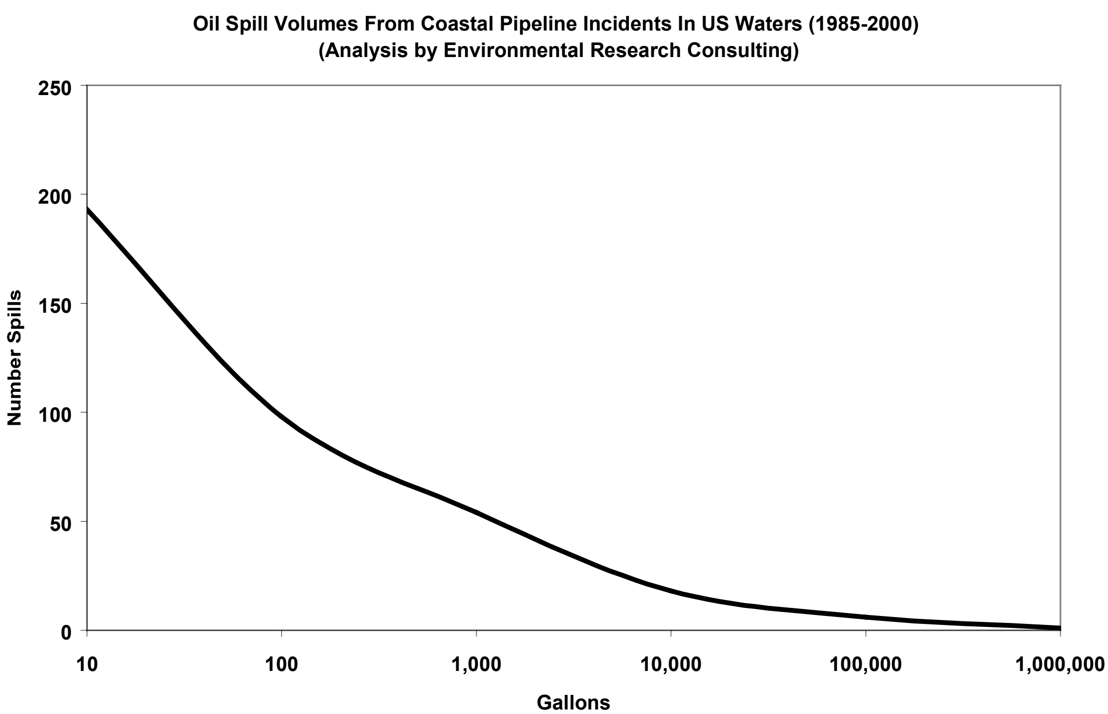
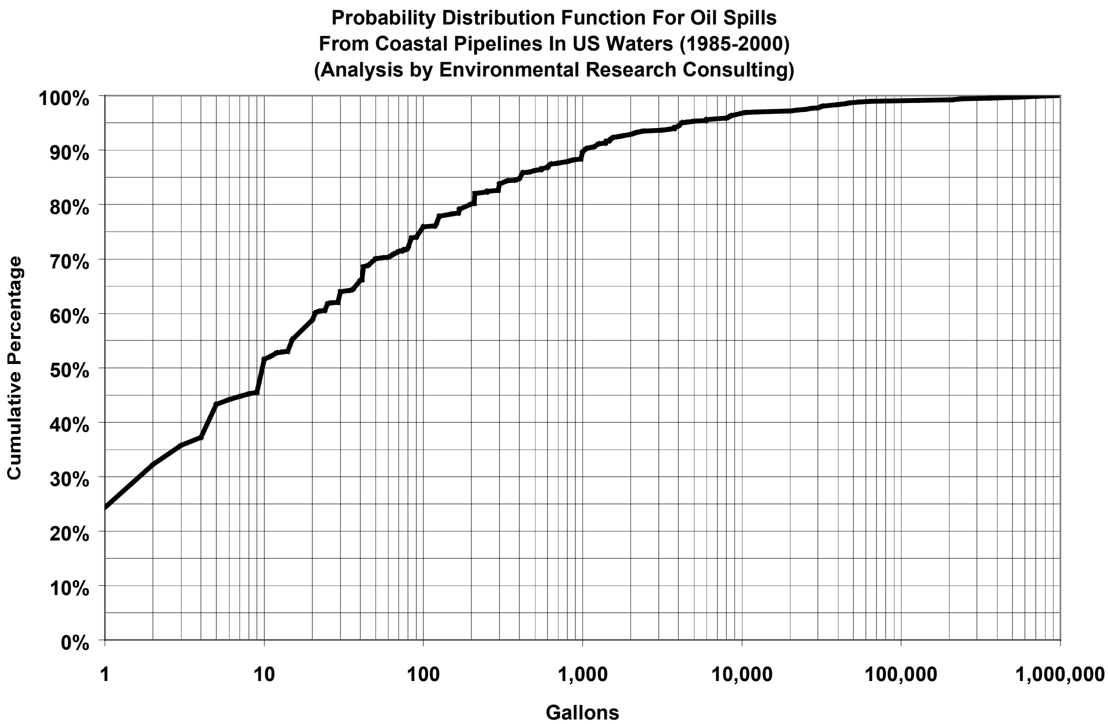


Figure 7.2



7.2 US Coastal Facility Spills (Excluding Coastal Pipelines)

Figure 7.3

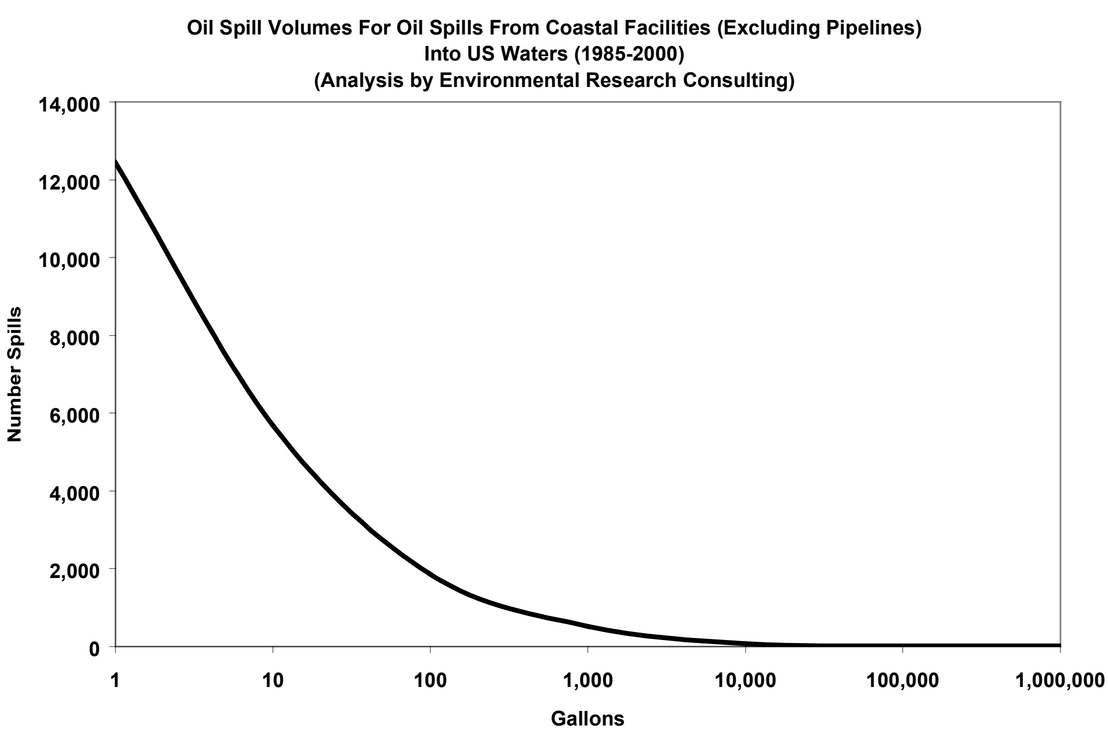
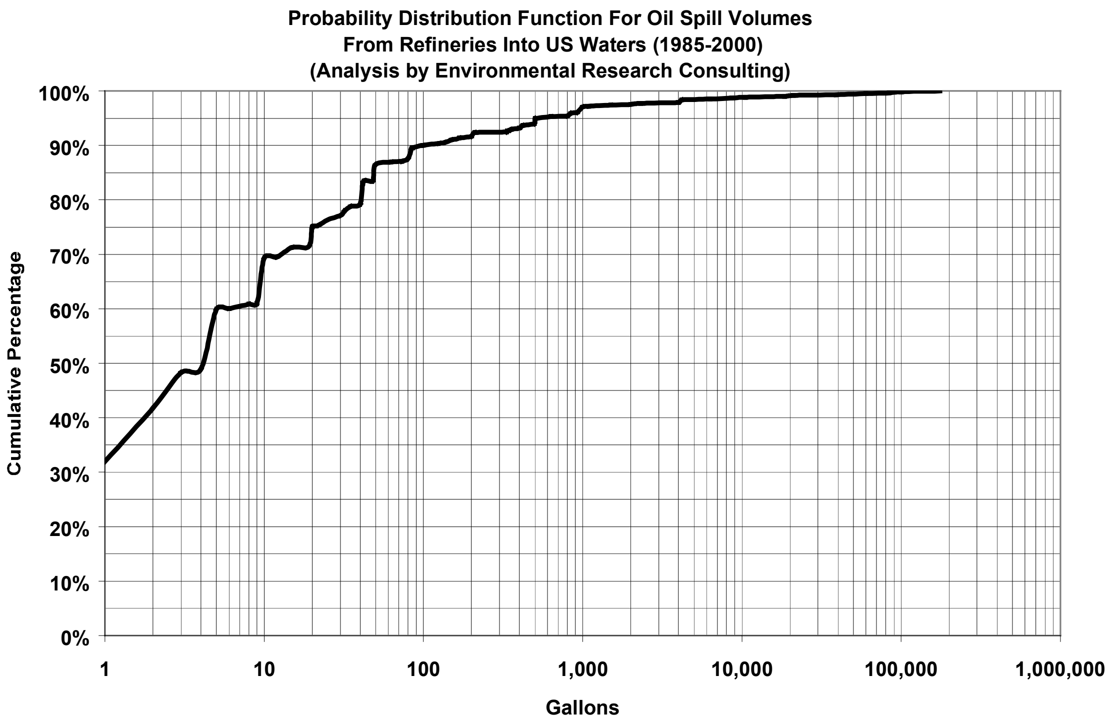


Figure 7.4



7.3 US Coastal Refinery Spills

Figure7.5

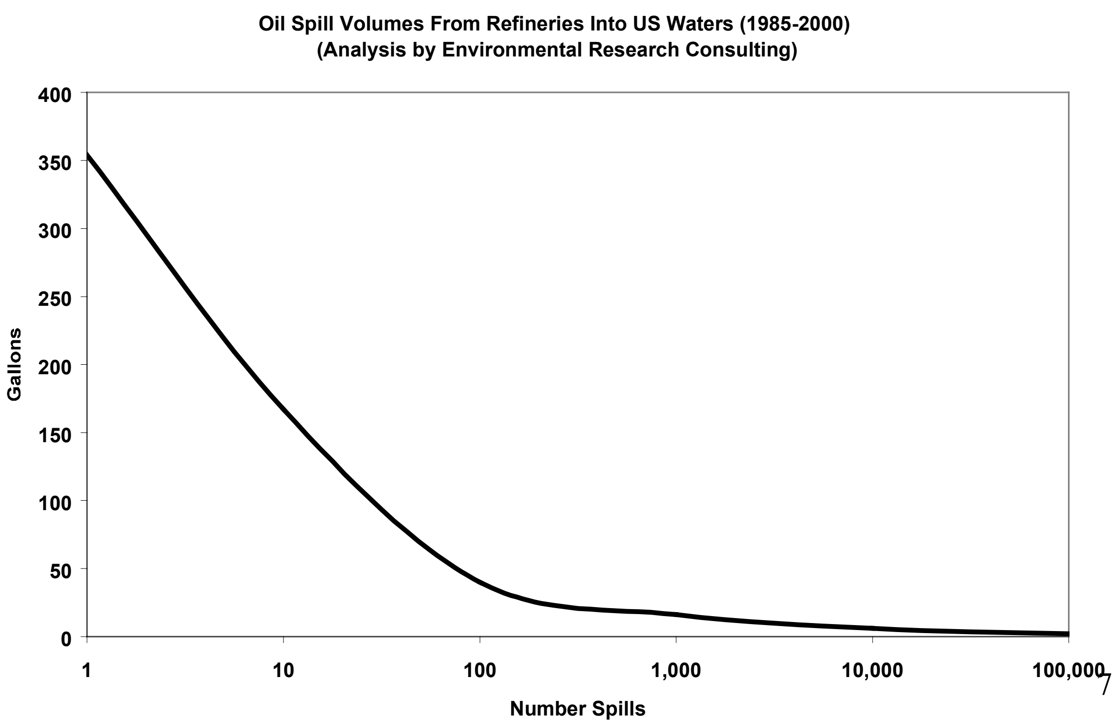
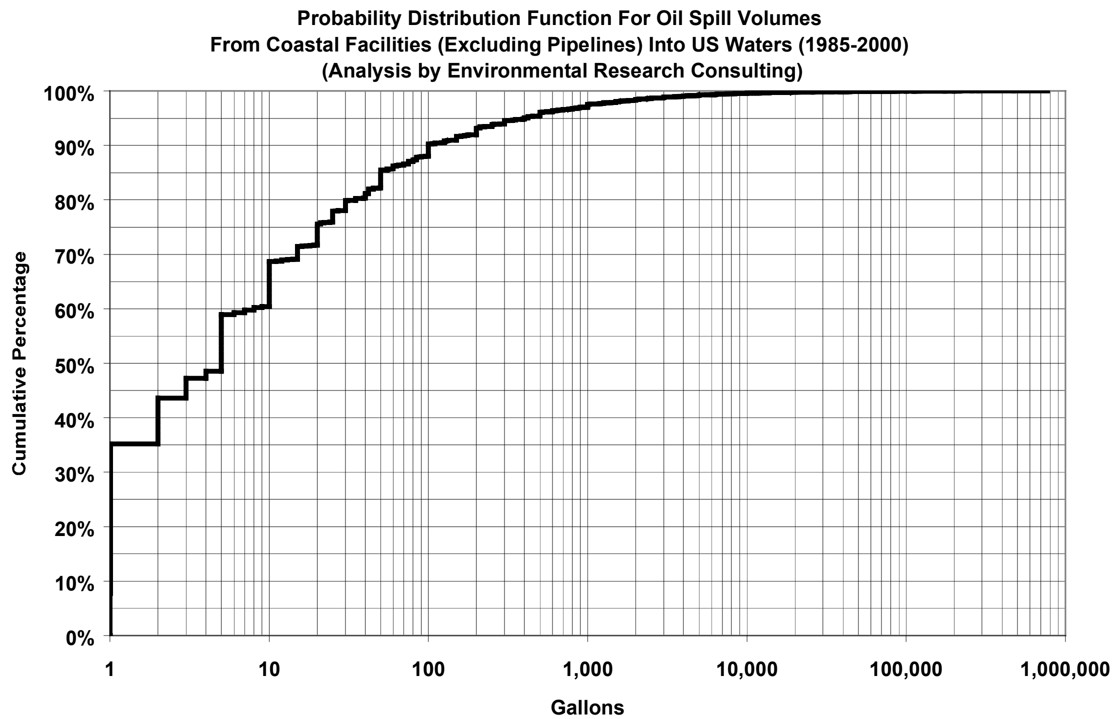


Figure 7.6



7.4 US Coastal Storage/Transfer Facility Spills

Figure 7.7

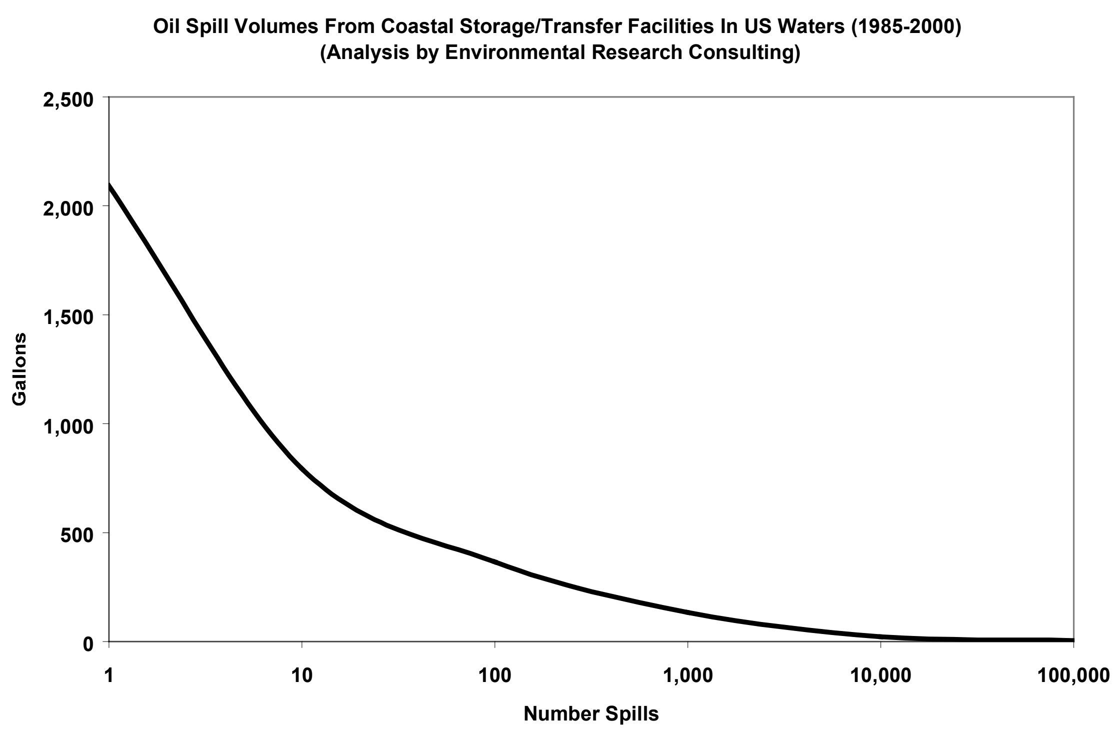
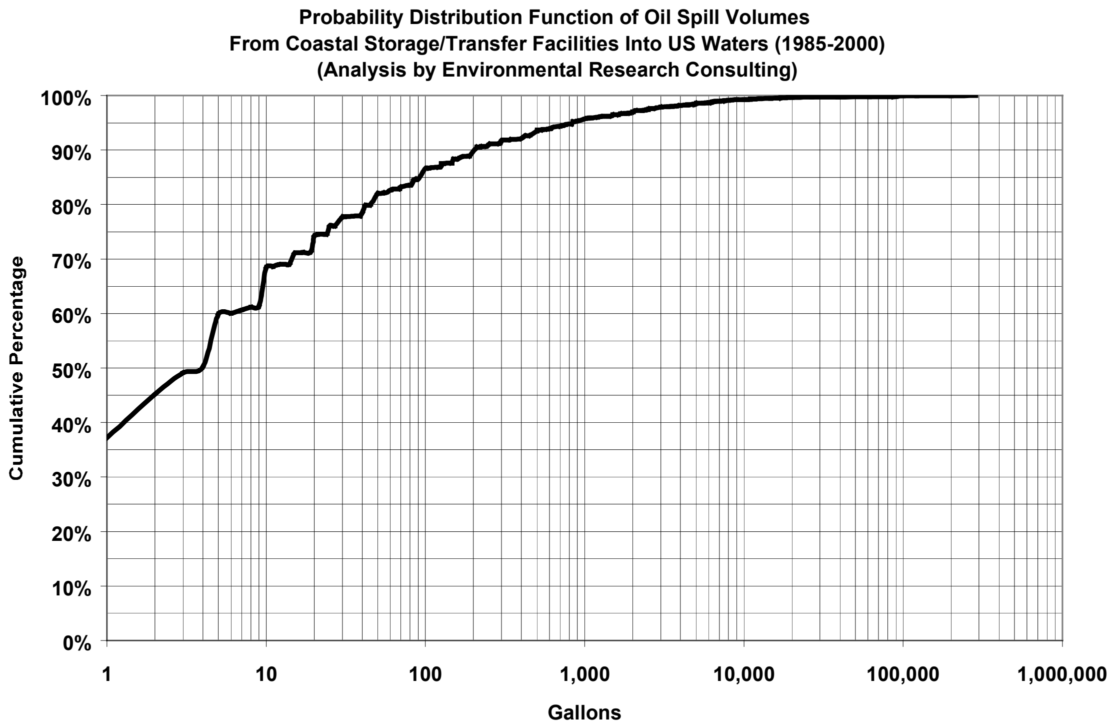


Figure 7.8



7.5 US Coastal Manufacturing Facility Spills

Figure 7.9

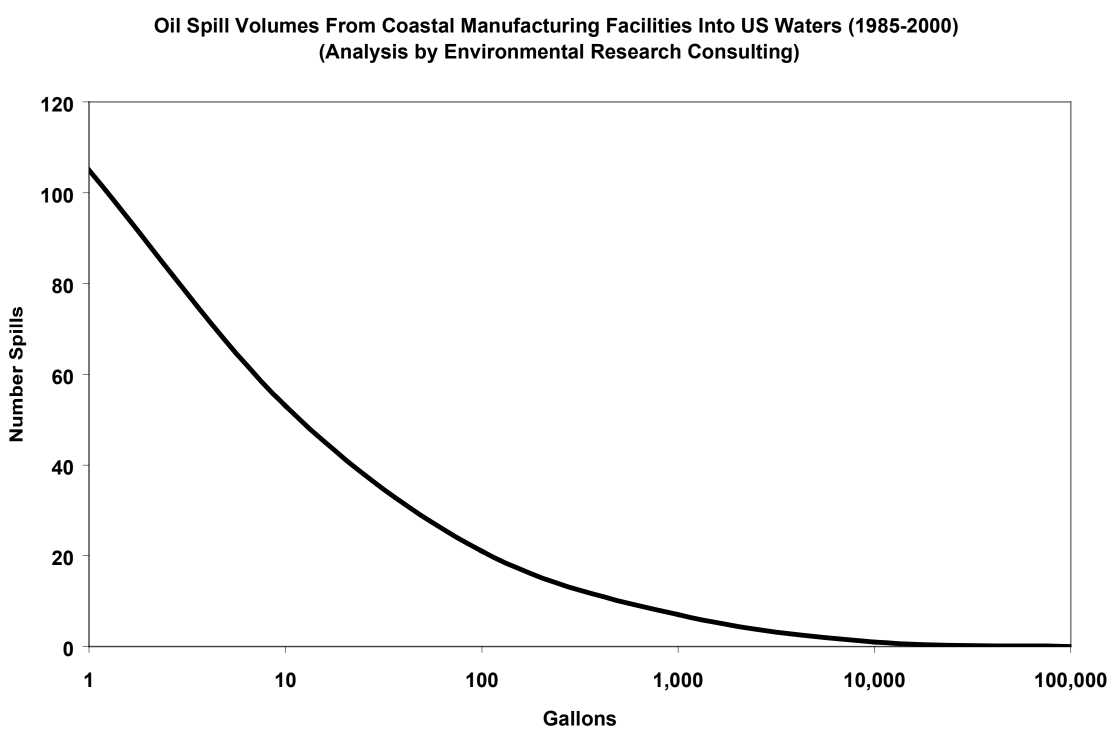


Figure 7.10

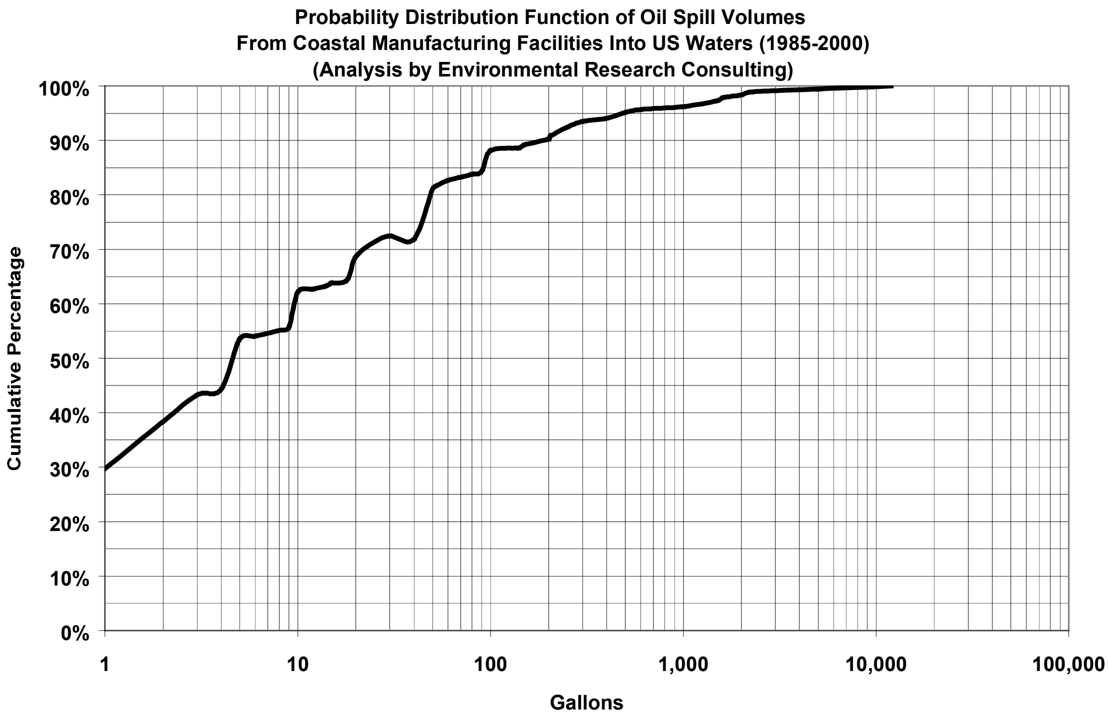


Table 7.1

Oil Spill Volumes From Facilities Into US Waters (1985-2000)							
Spill Sources	**Percentile Spills (gallons)**						
	10th	**25th**	**50th**	**75th**	**90th**	**95th**	**Worst Case Discharge**
Coastal Pipelines	1	1	10	100	1,000	5,000	1,000,000
Coastal Facilities (ALL)	1	1	5	20	100	300	770,000
Coastal Refineries	1	1	4	20	100	500	175,000
Coastal Storage/Transfer	1	1	4	20	200	900	290,000
Coastal Manufacturing	1	1	5	45	200	500	12,000

Percentile spills are defined as the percentage of spills that are *smaller* than this size, e.g., the 95th percentile spill is that spill size which is larger than 95% of spills (only 5% of spills are larger than this; 95% of spills are smaller than this).
Analysis by Environmental Research Consulting.

Oil Spills From Coastal Facilities Into US Waters (1985-2000)
By Oil Type

Source Type		Oil Type					
		Gasoline	Light Distillates	Crude	Heavy Fuel	Waste	Other
Coastal Pipelines	Spill Number	48	206	418	70	18	19
	Total Spilled (gal)	359,296	2,404,568	1,091,288	10,943	855	3,799
	Avg. Spill Size	7,485	22,685	2,611	156	5	200
	% Total (#)	7.1%	15.6%	61.6%	10.3%	2.7%	2.8%
	% Total (Volume)	9.3%	62.1%	28.2%	0.3%	<0.1%	0.1%
Coastal Refineries	Spill Number	41	117	108	113	77	129
	Total Spilled (gal)	102,251	12,426	151,270	108,220	114,252	185,179
	Avg. Spill Size	2,494	106	1,401	958	185	1,435
	% Total (#)	7.0%	20.0%	18.5%	19.3%	13.2%	22.1%
	% Total (Volume)	17.8%	2.2%	26.4%	18.9%	2.5%	32.3%
Coastal Storage/ Transfer	Spill Number	208	874	778	893	271	386
	Total Spilled (gal)	53,327	154,417	1,032,062	166,989	222,431	342,604
	Avg. Spill Size	256	177	1,327	187	821	888
	% Total (#)	6.1%	25.6%	22.8%	26.2%	7.9%	11.3%
	% Total (Volume)	2.7%	7.8%	52.3%	8.5%	11.3%	17.4%
Coastal Manufacture	Spill Number	2	45	4	80	32	22
	Total Spilled (gal)	5	18,811	3,257	9,862	957	872
	Avg. Spill Size	25	418	814	123	30	40
	% Total (#)	1.1%	24.3%	2.2%	43.2%	17.3%	11.9%
	% Total (Volume)	<0.1%	55.7%	9.6%	29.2%	2.8%	2.6%
Analysis by Environmental Research Consulting							

8.0 Summary

Based on the analyses conducted the most-probable and theoretical worst-case discharge spill volumes shown in Table 8.1 are recommended for use in contingency planning.

For vessel spills, volumes for spills due to accidents (collisions, allisions, groundings, structural failure, fire, and sinking) were derived using the US national data applied to Washington State (Puget Sound) vessel traffic data. *Most-probable* worst-case discharge volumes are based on the largest percentage cargo or bunker fuel lost during 1985-2000 for each vessel type. *Theoretical* worst-case discharge volumes are derived from the actual cargo and bunker fuel volumes carried on vessels transiting Washington state waters.

For vessel spills involving lightering and fueling, illegal discharges, and other pollution incidents, spill volumes can be derived from either the historical Washington spill data or the US national data. The larger of the volumes (from US national data) would probably constitute the more *cautionary* values for contingency planning and are presented in Table 8.1.

For coastal facilities, the spill volumes are based on the probability distribution functions derived from US national data.

Table 8.1

Recommended Contingency Planning Standards For Washington State Waters				
Spill Type	**Oil Types[1]**	**Spill Volumes (gallons)**		
		Median	**Most-Probable WCD**	**Theoretical WCD**
Crude Tanker CAG	C	700,000	12,000,000	32,718,000
Crude Tanker FAIL	C	3,000	3,800,000	32,718,000
Product Tanker CAG	D,G,B	700,000	12,000,000	10,941,000
Product Tanker FAIL	D,G,B	3,000	3,800,000	10,941,000
Tanker Light/Load	C,H,I	6	100,000	not defined
Tanker Pollution	C,H,I	3	50,000	not defined
Barge CAG	C,D,G,B	800	880,000	3,800,000
Barge FAIL	C,D,G,B	20	1,031,000	3,800,000
Barge Light/Load	C,D,G,B	20	155,000	not defined
Barge Pollution	C,D,G,B	2	195,000	not defined
Freighter CAG	H,I	4,200	825,600	825,600
Freighter FAIL	H,I	70	825,600	825,600
Freighter Light/Load	H,I	8	23,300	not defined
Freighter Pollution	H,I	5	93,000	not defined
Passenger Accidents	H,I,D	400	141,000	141,000
Passenger Fueling	H,I,D	15	1,000	not defined
Passenger Pollution	H,I,D	9	5,300	not defined
Fishing Accidents	D	310	165,100	165,100
Fishing Fueling	D	4	35	not defined
Fishing Pollution	D	9	120,000	not defined
Coastal Pipeline	C,G,D,B	100	1,000,000	not defined
Coastal Refinery	C,G,D,B	20	770,000	not defined
Coastal Manufacture	G,D,B	45	12,000	not defined
Coastal Storage/Fuel	C,G,D,B	20	290,000	not defined

[1]Oil types: C = crude; H = heavy fuel oil; I = intermediate fuel oil; D = diesel, No. 2 fuel; G = gasoline; B = bunker C, No. 6 fuel.
Analysis by Environmental Research Consulting

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